THE DISRUPTER SERIES: 3D PRINTING

HEARING

BEFORE THE

SUBCOMMITTEE ON COMMERCE, MANUFACTURING, AND TRADE

OF THE

COMMITTEE ON ENERGY AND COMMERCE

HOUSE OF REPRESENTATIVES

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C O N T E N T S

WITNESSES

SUBMITTED MATERIAL

[1] Mr. Orringer did not answer submitted questions for the record by the time of printing.

THE DISRUPTER SERIES: 3D PRINTING

FRIDAY, FEBRUARY 26, 2016

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON COMMERCE, MANUFACTURING, AND TRADE,
COMMITTEE ON ENERGY AND COMMERCE,
Washington, DC.

The subcommittee met, pursuant to call, at 9:59 a.m., in room 2123, Rayburn House Office Building, Hon. Michael C. Burgess (chairman of the subcommittee) presiding.

Members present: Representatives Burgess, Lance, Harper, Guthrie, Bilirakis, Brooks, Schakowsky, Clarke, Kennedy, Cárdenas, Welch, and Pallone (ex officio).

Staff present: Mike Bloomquist, Deputy Staff Director; Leighton Brown, Deputy Press Secretary; Rebecca Card, Assistant Press Secretary; James Decker, Policy Coordinator, Commerce, Manufacturing, and Trade; Andy Duberstein, Press Secretary; Graham Dufault, Counsel, Commerce, Manufacturing, and Trade; Melissa Froelich, Counsel, Commerce, Manufacturing, and Trade; Paul Nagle, Chief Counsel, Commerce, Manufacturing, and Trade; Tim Pataki, Professional Staff Member; Olivia Trusty, Professional Staff Member, Commerce, Manufacturing, and Trade; Dylan Vorbach, Legislative Clerk; Michelle Ash, Democratic Chief Counsel, Commerce, Manufacturing, and Trade; Christine Brennan, Democratic Press Secretary; Lisa Goldman, Democratic Counsel, Commerce, Manufacturing, and Trade; Caroline Paris-Behr, Democratic Policy Analyst; Timothy Robinson, Democratic Chief Counsel; and Diana Rudd, Democratic Legal Fellow.

Mr. BURGESS. The Subcommittee on Commerce, Manufacturing, and Trade will now come to order. I will recognize myself for 5 minutes for the purpose of an opening statement.

OPENING STATEMENT OF HON. MICHAEL C. BURGESS, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TEXAS

Today we are continuing our Disrupter Series and focusing today on additive manufacturing, also what is known as 3D printing. Additive manufacturing has disrupted the industries it has impacted, not just by challenging incumbents, but also by lowering cost and increasing efficiency.

Harnessed properly, this is another example of how innovation is creating jobs and opportunity and helping set the stage for a revival of manufacturing in the United States.

Additive manufacturing has been around since the 1980s with the patent for stereolithography issued to Charles Hull, the founder

of one of the companies testifying today, 3D Systems. About 30 years later, surveys show that about two-thirds of industrial manufacturers say they are implementing additive manufacturing either by experimenting or using it to create prototypes of finished products, and the 3D printing industry is expected to grow from the $6 billion it is today to over $20 billion in a mere 5 years' time.

3D printing has already woven its way into our manufactured products in subtle ways. For example, some of the commercial airliners we all fly will soon use 3D-printed parts in their engines, and GE will testify about that today. Many of the cars on the road have had their development sped up dramatically thanks to 3D-printed prototypes.

Additive manufacturing has plugged itself into a growing proportion of the manufacturing supply chain because the designs are flexible and they are a naturally better solution for certain tasks.

But 3D printing is also making a splash in less subtle ways. People around the globe are benefitting from prosthetic limbs, which were otherwise unaffordable. Surgeons can create accurate surgical guides which reduce errors and as a result will save lives. Scientists have begun experimentally printing human cell structures using a person's DNA. That resulted as a logical use of life's own building blocks, but certainly potentially revolutionary for patients.

In my district, 3D printing is enabling businesses to get the job done more efficiently. I have a constituent back home, his name is Adrian Murray, he runs a hotrod modification shop called Painless Performance, and he provides customers with custom wiring harnesses for their classic cars. These parts are no longer manufactured on an assembly line, but using a 3D printing prototype offered by the Specialty Equipment Manufacturers Association, Painless Performance is able to speed up the development process. And I think we are going to show a video clip of that, if the technology doesn't fail us, and I will continue talking while that runs.

[Video shown.]

As the subcommittee with jurisdiction over vehicle safety, we are especially interestedin ways that vehicle suppliers and manufacturers are using polymers and plastics to enhance safety.

Can we just turn the sound down on that, because it is mostly the visual that we want.

Carbon fiber-reinforced plastics have 12 times the energy absorption capabilities, while adding half of the weight of some comparable metal parts. Additive manufacturing is helping automakers and part suppliers integrate these innovative materials into cars, which is making a safer and improving fuel efficiency. As 3D printers become more affordable, the universe of people able to print 3D-printed objects on their own expands.

One of the things in research for this hearing, my staff found an article for me, it is actually from Australia, that it talks about Ralph Mobbs, a neurosurgeon from Prince of Wales Hospital in Sydney. And in resecting a tumor in a patient, he had to replace the top two vertebras, pretty difficult operation, and, obviously, without the proper type of prosthetic it would have been impossible.

So the surgeon worked with an Australian medical device manufacturer to craft replicas of the patient's top two vertebra out of ti-

tanium. I just want to read you a quote from the surgeon—and mind you, he is from Australia, so he talks funny, I am sure.

"To be able to get the printed implant that you know will fit perfectly because you have already done the operation on a model, it was a pure delight. It was as if someone had switched on a light and said, 'Crikey, if this isn't the future, well, I don't know what is.'"

So, Dr. Mobbs, I agree with you: If this isn't the future, I don't know what is.

[The prepared statement of Mr. Burgess follows:]

PREPARED STATEMENT OF HON. MICHAEL C. BURGESS

Today we continue the Disrupter Series with additive manufacturing, or 3–D printing. Additive manufacturing has disrupted the industries it has impacted not just by challenging incumbents, but also by lowering costs and increasing efficiency. Harnessed properly this is another example of how innovation is creating jobs, opportunity and a revival in manufacturing in the U.S.

Additive manufacturing has been around since the 1980s, with the patent for stereolithography issued to Charles Hull-the founder of one the companies testifying today, 3D Systems.

About 30 years later, surveys show that about two-thirds of industrial manufacturers say they are implementing additive manufacturing, either by experimenting or using it to create prototypes or finished products. And the 3D printing industry is expected to continue growing from about $6 billion today to about $21 billion by 2020.

3D printing has already woven its way into our manufactured products in subtle ways. For example, some of the commercial airliners we fly will soon use 3–D printed parts in their engines, as GE will testify. And many of the cars on the road have had their development sped up dramatically thanks to 3D printed prototypes.

Additive manufacturing has thus plugged itself into a growing proportion of manufacturing supply chains because the designs are flexible and are naturally a better solution for certain tasks.

But 3D printing is also making a splash in less subtle ways. People around the globe are benefiting from prosthetic limbs that were otherwise unaffordable. Surgeons can create accurate surgical guides, which reduce errors and as a result save lives.

Scientists have begun experimentally printing human cell structures using a person's DNA-a result that is a logical use of life's building blocks, but potentially revolutionary for patients in need of transplants.

In my district, 3D printing is enabling businesses to get the job done more efficiently. My constituent Adrian Murray's auto supply company, Painless Performance, provides customers with custom wiring harnesses for classic cars. These parts no longer have an assembly line, but by using the 3D printing prototype service offered by the Specialty Equipment Manufacturers Association (or SEMA) Garage, Painless Performance is able to speed up the development process.

If you turn your attention to the monitors, you can see one of these products being made.

As the subcommittee with jurisdiction over vehicle safety, we are especially interested in ways vehicle suppliers and manufacturers are using polymers and plastics to enhance safety. Carbon fiber reinforced plastics have 12 times the energy absorption capabilities while adding half of the weight of some comparable metal parts. Additive manufacturing is helping automakers and parts suppliers integrate these innovative materials into cars, which is making us safer while improving fuel efficiency.

Of course, as printers become more affordable, the universe of people able to 3D print objects on their own expands.

Many have raised the caution that this in turn could facilitate an end user to print firearms that circumvent Federal law or to use for an illegal purpose. Policymakers rightly take these concerns seriously and they will continue to be debated in Congress and across the country.

The task at hand this morning is to introduce this subcommittee to the technologies behind additive manufacturing, its beneficial uses, what it means for innovation and job creation, and the friction it has encountered either from market forces or the Government.

I thank the witnesses for educating us on this exciting technology and look forward to a thoughtful discussion.

Mr. BURGESS. I will now turn to Ms. Clarke from New York, ranking member of the subcommittee, for an opening statement.

OPENING STATEMENT OF HON. YVETTE D. CLARKE, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW YORK

Ms. CLARKE. Good morning, Chairman Burgess and members of this morning's panel. Mr. Chairman, thank you for holding this hearing on 3D printing.

For many of us, when we think of 3D printing, we think of plastic toys, key chains, and other trinkets, but 3D printing is about more than just the novelty of printing in plastic. This technology has many applications that we are only starting to explore.

3D printers enable small-scale personalized production that gives consumers more choice and convenience. Consumers can order affordable custom-printed items, from cell phone cases to shoes and prescription eyewear.

3D printers help product designers by allowing them to print prototypes more easily. Manufacturers can print replacement parts on demand. Prosthetics can make customized to make people who have lost a limb more comfortable. And recently, a 3D-printed vertebra, as our chairman has indicated, was implanted into a child with bone cancer.

While today we are mostly printing in plastic and metal, 3D bioprinting opens a whole new world of possibilities in the medical field. Doctors may one day be able to grow needed organs for transplants or skin for prosthetic limbs or skin grafts.

The future potential of this technology is one more reason why we need to increase our Federal investments in research and innovation.

But as we think about the tremendous potential of 3D printing, we also need to consider possible risks and challenges. Here are some of the questions on my mind. How should we protect consumers when the consumer doesn't buy the product but rather the blueprint to make a product? How does 3D printing work with our existing laws on intellectual property? And what should people be able to make with 3D printers?

I am especially concerned about 3D-printed weapons. Think about this: If someone has access to a 3D printer, all they need is the right blueprint. When the gun buyer is now the gun manufacturer, who does the background check? Who is responsible for keeping weapons out of the wrong hands? This isn't theoretical. The first 3D-printed gun was made 3 years ago.

An all-plastic gun would be a violation of the Undetectable Firearms Act, but a law banning the manufacture of nonmetal guns only goes far when a plastic firearm can be made at home. And we may not be far from seeing metal guns being printed at home.

Those who design blueprints for 3D printing and provide 3D printing capability must take responsibility to ensure that their business does not endanger other lives, and we in Congress need to make sure that our laws are up to date with today's technology.

I look forward to hearing from our witnesses on the potential for 3D printing as well as your perspectives on how we deal with some of these challenges.

Having said that, Mr. Chairman, I yield back.

Mr. BURGESS. The Chair thanks the gentlelady. The gentlelady yields back.

The Chair would inquire of Mr. Pallone if he seeks time for an opening statement.

Mr. PALLONE. I do.

Mr. BURGESS. Recognized for 5 minutes for an opening statement.

OPENING STATEMENT OF HON. FRANK PALLONE, JR., A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW JERSEY

Mr. PALLONE. Thank you, Mr. Chairman.

3D printers and the products they produce have the potential to transform and improve our lives. It is remarkable to think about what is already possible in this space, not to mention the possibilities for the future.

Today, 3D printers are driving innovation in American factories, schools, hospitals, and homes. All around the country, health researchers are using 3D printers to develop new approaches to tissue transplant and regeneration. The level of customization permitted by 3D printing can allow prosthetics, hearing aids, and dental aligners to be made more comfortable, effective, and affordable.

And now think about the potential for 3D printers to transform the way cutting-edge medical care is distributed. The latest and greatest discoveries would no longer be limited to those who have access to a select group of medical facilities. Instead, 3D printers could help to easily reproduce new treatments and therapies at any hospital throughout the country and the world.

3D printing technology also has the potential to help build a more dynamic and inclusive workforce. At Rutgers University in my district, innovators created 3D-printed braille maps that make a local vocational training center easier to navigate for the visually impaired.

Additionally, 3D printers allow people to create prototypes of new designs or inventions at a lower cost than traditional production techniques, thus helping underrepresented communities gain access to entrepreneurship.

The development of 3D printing technology is a great example of how effective public-private partnerships can be. This administration and members such as Representative Kennedy have worked to strengthen Federal support for 21st century manufacturing technology such as 3D printing, and I look forward to hearing how the National Network for Manufacturing Innovation is working with companies, such as those represented by our witnesses today, to promote American innovation and safeguard the future of domestic manufacturing.

And as with all new technologies, the further adoption of 3D printing, especially its home use, raises safety and regulatory questions. Many of us have seen the media coverage about 3D-printed guns. While the ability to make guns at home may not be new, the

ability to make them easily and cheaply poses new safety risks, and increasing the number of guns made outside of the registration process could increase the number of guns in the hands of criminals.

In addition, questions have been raised about how to protect intellectual property as 3D printers proliferate. There have been concerns about some types of inks used in 3D printing containing BPA, a chemical that the FDA has banned from use in baby bottles and children's drinking cups.

3D printing offers enormous possibilities for innovation in manufacturing, increased opportunities for entrepreneurship, and convenience and customization that was not available before. So it is exciting to think about the possibilities, and I am confident these innovations can be coupled with consumer protections so that they really can improve people's lives.

Did you want some time?

Mr. KENNEDY. I will take 30 seconds.

Mr. PALLONE. Yes. I will yield you the rest of my time.

Mr. KENNEDY. Thank you. Thank you very much, Mr. Pallone. And I want to thank the chairman for calling this hearing.

I was really excited just to get a chance to listen to all of you and understand a little bit about how the national institutes are going building out the progress. I have been bragging about you like crazy everywhere, so hopefully it is good. And very much look forward to understanding and getting some lessons learned from you about what is working well, where we can improve as other institutes are stood up around the country, how we can try to learn from your success.

Most importantly, trying to understand how Government can be a positive source for innovation and trying to lower some of the barriers to entry and the risks that local innovators take and small businesses take and trying to make sure we can spur the next generation of manufacturing here in the United States, what that also means for the workforce, integration with our workforce, workforce training, all the way up the supply chain.

So I am grateful for the opportunity to be here, grateful that all of you are willing to come testify, and look forward to learning from you over the course of the rest of the morning.

Thank you. I yield back.

Mr. BURGESS. The Chair thanks the gentleman. The gentleman yields back.

Seeing no other member seeking time, we will conclude with member opening statements. And the Chair would remind members that, pursuant to committee rules, all members' opening statements will be made part of the record.

We do want to thank our witnesses for being here today, taking time out of your day to testify before the subcommittee. Today's witnesses will have the opportunity to give opening statements, and then we will follow with questions from members.

Our witness panel for today's hearing includes Mr. Neal Orringer, Vice President for Alliances and Partnerships, 3D Systems; Mr. Alan Amling, Vice President for Global Logistics and Distribution Marketing with UPS; Mr. Ed Morris, Director of National Additive Manufacturing Innovation at the National Center

for Defense Manufacturing and Machining; and Dr. Herderick, the Additive Technologies Leader for Corporate Supply Chain and Operations within General Electric.

So we appreciate all of you being here today. We will begin the panel with Mr. Orringer.

And, Mr. Orringer, you are recognized for 5 minutes for an opening statement, please.

STATEMENTS OF NEAL J. ORRINGER, VICE PRESIDENT, ALLIANCES AND PARTNERSHIPS, 3D SYSTEMS CORP.; ALAN AMLING, VICE PRESIDENT OF MARKETING, GLOBAL LOGISTICS, AND DISTRIBUTION, UNITED PARCEL SERVICE, INC.; ED MORRIS, VICE PRESIDENT AND DIRECTOR, AMERICA MAKES–THE NATIONAL ADDITIVE MANUFACTURING INNOVATION INSTITUTE, NATIONAL CENTER FOR DEFENSE MANUFACTURING AND MACHINING; AND EDWARD D. HERDERICK, PH.D., ADDITIVE TECHNOLOGIES LEADER, G.E. CORPORATE SUPPLY CHAIN AND OPERATIONS

STATEMENT OF NEAL J. ORRINGER

Mr. ORRINGER. Thank you. Thank you, Mr. Chairman, Congresswoman Clarke, and members of the distinguished subcommittee. Thank you for the invitation to address you today.

I am honored to discuss a critically important topic, how additive manufacturing is revolutionizing the delivery of health care. In 1983——

Mr. BURGESS. Mr. Orringer, is the green light on in your microphone?

Mr. ORRINGER. It is.

Mr. BURGESS. You may need to pull it a little closer.

Again, I would stress that even though this is the premier technology committee in the United States Congress, we have pretty low-tech equipment. But please continue.

Mr. ORRINGER. How is this? OK.

In 1983, my company's founder, Chuck Hull, invented 3D printing. He was applying a process called stereolithography to physically replicate an eyecup that was designed and digitally drawn on a computer. His patent was granted in 1986, and the business took off from there. More than 30 years later, the industry is in full throttle.

For its own part, 3D Systems is the world leader in additive manufacturing and the only major U.S.-based 3D printing company. From the offset, we have catalyzed continuous innovation in health care. So I guess I would amend Dr. Mobbs' comments and say the future is now.

In the early 1990s, we revolutionized the manufacturing of hearing aids, rapidly customizing the form and fit to an individual's ear with unparalleled precision, helping build wireless devices with comfortable biocompatible materials. And today, 99.5 percent of all hearing aids are 3D printed worldwide.

A decade later, we helped two graduate students from Stanford University discover a better way to straighten teeth. With our technology, they manufactured what became Invisalign, which are clear orthodontic aligners, as has been discussed. Today, Align is a world

leader in mass customization, accuracy, and comfort, producing over 20 million individual aligners in the last 12 months alone.

So 3D printing continues to advance significant breakthroughs in the field of precision medicine. Now, that is a movement that has been championed by the FDA that tailors medical treatments intensively to individual characteristics of each patient. So as part of this movement, together with genomics, regenerative medicine, computational biology, and medical imaging, 3D printing is once again revolutionizing the practice of saving and improving lives.

Now, today I would like to concentrate on three areas: virtual surgical planning, fabrication of advanced implants and devices, and new modeling processes. Virtual surgical planning is what I would start with first.

VSP empowers surgeons with unparalleled precision in the most complex procedures. It significantly reduces the time in the surgical theater and saves lives. Our experts interact directly with doctors, receiving data from CT scans, and then design and build surgical guides that are placed on a patient to support a particular procedure.

[Video shown.]

Mr. ORRINGER. We are showing a video right now in the hearing room to highlight the case of Blessing Makwera. He sustained a land mine injury to his upper and lower jaws, tongue, lip, and teeth. Blessing's spirit and courage are truly inspirational, and today he can smile.

Now, 3D Systems worked with Joel Berger, an oral and maxillofacial surgeon at Sharp Memorial Hospital in San Diego, California, to rebuild Blessing's face and give him new teeth. The fibula free flap operation involves taking bone, tissue, and vessels from the fibula and reconfiguring them to form an upper and lower jaw connected to blood vessels in the neck. We used CT scans to extract 3D anatomical information needed to visualize the surgery in 3D and map out the surgical plan.

Blessing required a number of 3D tools, including a mandible and maxilla cutting tools of the lower and upper jaw to guide the surgeon's saw blades in the operating room. It is an inspirational story among tens of thousands over the last several years.

Models and simulation. Aside from the surgical guides, Blessing's surgeons also used 3D printing models for reference during the operation. These models show surgeons what is hidden beneath layers of soft tissue, and it gave surgeons hands-on experience with Blessing's jaw and anatomy long before the surgery.

Finally, I want to talk not about customized tools but about how 3D printing is transforming wholesale production of medical devices and implants. I brought a titanium component of a hip transplant, which we 3D printed. Rather than go through the onerous process of building a cast mold, shaping and cooling, and then coating a single part, metal 3D printing allows us to consolidate the supply chain, saving time and resources. It also allows us to add functions to the part with designs that maximize bone cohesion, structures that simply cannot be built via any other manufacturing process.

So doctors and device manufacturers can send us data to engineer 3D models, and then we use direct metal printing to build

dozens of these titanium cups in a single build process. We have been working with U.S. and European regulators to ensure appropriate quality assurance in the process for an array of implants and devices.

In all these areas, we have a strong and constructive partner in the Federal Government. As we work to receive appropriate qualification for these products, it is essential we maintain an appropriate balance between promoting innovation and ensuring the safe delivery of care to patients.

As 3D printing improves the economics and the production of critical healthcare tools, I am hopeful we might someday see these efficiencies actually translate to lower costs for the patient. Integrating these novel processes and tools will require a greater understanding not only by the regulators, but the health insurance industry as well.

Now, in due time, perhaps it will be commonplace for these tools to be integrated into conventional building processes. It is time for 3D printing to be appreciated as an important instrument for mainstream quality care, and I look forward to discussing this and other issues with the committee today. Thank you.

[The prepared statement of Mr. Orringer follows:]

Statement by Neal J. Orringer

Vice President, Alliances and Partnerships

Disruptor Series: 3D Printing

before

The Committee on Energy and Commerce Subcommittee on Commerce, Manufacturing and Trade

U.S. House of Representatives

February 26, 2016

Mr. Chairman, Ranking Member Schakowksy, and members of this distinguished subcommittee, thank you for the invitation to address you today.

I am honored to discuss a critically important topic— how additive manufacturing (or 3D printing) is revolutionizing the delivery of health care.

Thirty Years of Invention and Solution Adoption

In 1983, my company's founder -- Chuck Hull invented 3D printing, applying a process called stereolithography to physically replicate a plastic eye-cup that was designed and digitally drawn on a computer. His patent was granted in 1986 and the business took off from there.

More than 30 years later, the industry is in full-throttle. For its own part, 3D Systems is the world leader in additive manufacturing, and the only major US-based 3D printing company. From the outset, we've catalyzed continuous innovation in health care—

In the early 1990s we revolutionized manufacturing of hearing aids, rapidly customizing the form and fit to an individual's ear with unparalleled precision, helping build wireless devices with comfortable biocompatible materials. Today, 99.5 percent of all hearing aids are 3D-printed world-wide.

A decade later, we helped two graduate students from Stanford University discover a better way to straighten teeth. With our technology, they manufactured what became Invisalign clear orthodontic aligners. Today, Align is a world leader in mass customization, accuracy, and comfort, producing over 20 million individual aligners in the last 12 months alone.

Promise of Precision Medicine

3D printing continues to advance significant breakthroughs in the field of "Precision Medicine" – a movement championed by the Food and Drug Administration that tailors medical treatments intensively to individual characteristics of each patient. As part of this movement, together with genomics,

regenerative medicine, computational biology, and medical imaging, 3D printing is once again revolutionizing the practice of saving and improving lives.

Today, let's concentrate on three key areas: virtual surgical planning, fabrication of advanced implants and devices, and new modeling processes.

Virtual Surgical Planning. VSP empowers surgeons with unparalleled precision in the most complex procedures. It significantly reduces time in the surgical theater and saves lives. Our experts interact directly with doctors, receiving data from CT scans, and then design and build surgical guides that are placed on a patient to support a particular procedure. We are showing a video in the hearing room today highlighting the case of Blessing Makwera. He sustained a landmine injury to his upper and lower jaws, tongue, lips and teeth. Blessing's spirit and courage are truly inspirational; and today he can smile.

3D Systems worked with Dr. Joel Berger, oral and maxillofacial surgeon at Sharp Memorial Hospital in San Diego, California to rebuild Blessing's face and give him new teeth. The fibula free flap operation involves taking bone, tissue and vessels from the fibula and reconfiguring them to form an upper and lower jaw connected to blood vessels in the neck. We used CT scans to extract 3D anatomical information needed to visualize the surgery in 3D and map out the surgical plan.

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It's an inspiring story among tens of thousands over the last several years.

Models and Simulation. Aside from the surgical guides, Blessing's surgeons also used 3D printed models for reference during the operation. These models show surgeons what is hidden beneath layers of soft tissues. They gave surgeons hands-on experience with Blessing's jaw anatomy before starting surgery.

Advanced implants. Outside customized tools, 3D printing is also transforming whole-sale production of medical devices and implants. I brought a titanium component of a hip transplant which was 3D printed. Rather than go through the onerous process of building a cast mold, shaping, cooling, and then coating a single part, metal 3D printing allows us to consolidate the supply chain—saving time and resources. It also allows us to add functions to the part, with designs that maximize bone cohesion—structures that simply cannot be built via any other manufacturing process.

Doctors and device manufacturers can send us data to engineer 3D models and then we use direct metal printing to build dozens of these titanium cups in a single build process. We have been working with U.S. and European regulators to ensure appropriate quality assurance in the process for an array of implants and devices.

Keeping Pace with Innovation

In all these areas, we have a strong and constructive partner in the federal government. As we work to receive appropriate qualification for these products, it is essential we maintain an appropriate balance between promoting innovation and ensuring safe delivery of care to patients. As 3D printing improves the economics in the production of critical health care tools, I am hopeful we might someday see these efficiencies translate to lower costs for the patient. Integrating these novel processes and tools will require a greater understanding not only by regulators but the health insurance industry as well. In due time, perhaps it will be common place for these tools to be integrated into conventional billing processes. It is time for 3D printing to be appreciated as an important instrument for mainstream, quality care.

I look forward to discussing this and other issues with the Committee today.

Mr. BURGESS. The Chair thanks the gentleman.

The Chair recognizes Mr. Amling for 5 minutes to summarize your opening statement, please.

STATEMENT OF ALAN AMLING

Mr. AMLING. Good morning, Chairman Burgess, Ranking Member Schakowsky, members and staff of the committee, fellow witnesses, and attendees. My name is Alan Amling, and I am the Vice President of Marketing for UPS Global Logistics and Distribution. And during my 23-year tenure, I have helped our business develop and grow across all aspects of the e-economy and to launch innovative new solutions like carbon-neutral shipping.

While you are likely familiar with UPS' fleet of more than 100,000 brown trucks and our 425,000 employees globally, you may not know much about our supply chain business. More than 100 years ago, UPS started as a bike messenger in Seattle. In 2016, we operate one of the largest airlines in the world and offer global supply chain services, including ocean and air freight, ground freight, brokerage, and contract logistics, in addition to our more familiar brown package services.

Our global logistics network, made more intelligent and efficient, has the potential to radically reshape and reinvent economies. That is why we are interested in 3D printing, which could disrupt traditional manufacturing the way that e-commerce has disrupted traditional retail. Certainly, as this new technology becomes more widely available, there will be bumps in the road and hurdles to overcome, but the power of 3D printing cannot be overstated. It is disruptive not just because it is new, but because it helps small businesses and entrepreneurs do what they already need to do today, only better and less expensively.

Therefore, as 3D printing revolutionizes manufacturing, it will also affect our business of supply chains and eventually product pricing and the end consumer experience. 3D printing effectively means that businesses no longer will face minimum quantities. They will be able to order what they need when they need it. Upfront tooling cost, which is a big expense for businesses both large and small, makes 3D printing ideal for small batch production runs. And there is no tax on complexity. And what I mean by that is there is no corresponding increase in cost for a more complex design like this.

The disruptive nature of 3D printing, therefore, will create opportunities, but it will also require adjustments. As it becomes possible to send product design instructions via the Internet and print products locally, small businesses and entrepreneurs will be able to move from the idea phase to the production phase more quickly and cost effectively. Instead of delivering a product from a warehouse, products could be delivered from a 3D printing service offered at a retail outlet, such as a UPS store or right to your door.

Disruptive technology like 3D printing stands to help our customers do more with a lower environmental impact, all while benefitting consumers like you and me. It has the potential to increase profit margins within the supply chain by reducing cost, and that is good news for small businesses and entrepreneurs especially.

Additionally, it is important to understand that disruption will happen. There is almost no stopping the spread of technology and innovation. So we are either in the game or watching it, and I know what side of the equation UPS wants to be on.

And to that end, in anticipation of 3D printing's impact, UPS has already started putting 3D printers into UPS store locations. Our initial customer response was so positive that we have since expanded to more than 60 stores, with plans for continued growth.

Likewise, through our internal venture capital arm, we invested in a 3D printing manufacturer named CloudDDM and put their production facilities in the heart of our Louisville supply chain campus, just minutes from our global air hub. The operation has been up and running for a year and allows companies to order parts and prototypes to be printed late into the evening and have them delivered anywhere in the U.S. by the next morning. In doing so, UPS has helped to create a model that actually increases package demand and differentiates the company from other carriers. Now that is groundbreaking stuff.

Today, UPS is learning and adapting to new technologies, something we have done many times over our more than 100 years of operation. As proven over and over throughout history, those who embrace innovation and change early and often are the most richly rewarded, and disruptive technology, like 3D printing, has that incredible potential.

I commend the committee for their interest in understanding more about 3D printing and welcome this opportunity to share what we have learned up to this time. Thank you for your time today, and I look forward to answering questions.

[The prepared statement of Mr. Amling follows:]

Subcommittee on Energy and Commerce – "Disruptor Series" Hearing
Testimony Comments

Alan Amling
Vice President of Marketing, Global Logistics & Distribution
United Parcel Service
[redacted]

Good morning Chairman Burgess, Ranking Member Schakowsky, Members and Staff of the Committee, fellow witnesses and attendees. My name is Alan Amling and I am the Vice President of Marketing for a business unit of UPS called Global Logistics & Distribution. During my 23 year tenure with UPS, I've helped our business develop and grow across all aspects of the e-economy, and to launch innovative new solutions like carbon-neutral shipping.

While you are likely familiar with UPS's fleet of more than 100,000 brown trucks and our 425,000 employees globally, you may not know as much about our supply chain business.

More than 100 years ago, UPS started as a bike messenger service in Seattle. In 2016, we operate one of the largest airlines in the world -- and offer global supply chain services including ocean and air freight, ground freight, brokerage and contract logistics in addition to our more familiar brown package delivery services to your door.

Our global logistics networks – made more intelligent and efficient – have the potential to radically reshape and reinvent economies, as well as the value and supply chains that they serve. That's why UPS is investing heavily in 3-D printing, which could disrupt traditional manufacturing the way that e-commerce disrupted traditional retail.

Certainly, as this new technology becomes more widely available, there will be bumps in the road and hurdles to overcome. But the power of 3-D printing cannot be overstated. It's disruptive not just because it's new, but because it fundamentally helps businesses and entrepreneurs do what that they're already doing, only better or less expensively.

Therefore, as 3-D printing revolutionizes manufacturing, it will also affect our business of supply chains, and eventually product pricing and the end consumer experience. 3-D printing effectively means that businesses will no longer face:

- Minimum quantities – order what you need, when you need it.
- Upfront tooling costs – which is ideal for small batch production runs
- A "tax" on complexity – no corresponding increase in cost for a more complex design

The disruptive nature of 3-D printing, therefore, will create opportunities but also require adjustments, depending on your approach. The more products that can be printed on demand, the less there will be a need for warehousing infrastructure. As it becomes possible to send product design instructions via the Internet and print products locally, small businesses and entrepreneurs will be able to move from the idea phase to the production phase more quickly and cost-effectively. Instead of delivering a product from a warehouse, products could be "delivered" via a 3-D printing service offered at a retail outlet such as The UPS Store or to your door.

Disruptive technology like 3-D printing stands to help our customers do more – with a lower environmental impact – all while benefiting consumers like you or me. 3-D printing will create value for customers beyond traditional delivery services. It has the potential to increase profit margins within the supply chain by reducing cost. That's good news for small businesses and entrepreneurs especially.

Additionally, it's important to understand that disruption will happen – there's almost no stopping the spread of technology and innovation. So we can either be "in the game" or "watching it" – and I know which side UPS wants to be in the game with the customers we serve.

So, in anticipation of 3-D printing's impact, UPS has already started putting 3-D Printers in The UPS Store locations. Our initial customer response was so positive that we have since expanded to more than 60 stores, with plans for continued growth. Likewise through our internal venture capital arm, we

also invested in a 3-D Printing manufacturer named CloudDDM and put their production facilities in the heart of our Louisville supply chain campus, just minutes from our global air hub. The operation has been up and running for a year and allows companies to order parts and prototypes to be printed late into the evening and have them delivered anywhere in the U.S. by the next morning. In doing so, UPS has helped to create a model that actually increases package demand and differentiates the company from other carriers. That's groundbreaking stuff!

Today, UPS is learning and adapting to new technologies – something we've done many times in our more than 100 years of operations. As proven over and over throughout history, those who embrace innovation and change early on often are the most richly rewarded – and disruptive technology - like 3-D printing - has that incredible potential. I commend the Committee for the interest in understanding more about 3-D printing and welcome this opportunity to share what we have learned up to this time.

Thank you for your time today. I look forward to answering your questions.

Mr. BURGESS. The Chair thanks the gentleman.

Mr. Morris, you are recognized for 5 minutes to summarize your opening statement, please.

STATEMENT OF ED MORRIS

Mr. MORRIS. Good morning, Chairman Burgess, Vice Chairman Lance, Ranking Member Schakowsky, and members and staff of the committee. My name is Ed Morris. I am the Vice President and Director for America Makes, the National Additive Manufacturing Innovation Institute, and we are consciously dual branded as America Makes, the National Manufacturing Innovation Institute.

The maker community wants to deal with America Makes. We are happy to deal with industry. In the maker community you get a little leery of institutes, too formal, too official, so that is the reason for the dual branding.

We are operated by the National Center for Defense Manufacturing and Machining, a not-for-profit 501(c)(3) company that has been in existence for over 14 years solving technical, manufacturing, and business problems for our clients.

Our mission at America Makes begins with, why do we exist? And as we all know, the U.S. manufacturing economy, the economic engine of manufacturing, is nowhere near as robust as it has historically been or needs to be. So what are we going to do about that? We are taking this incredible technology of additive manufacturing and accelerating it in the United States by dealing with the technical issues, the technical barriers, doing technology transition to companies for real products, new companies, et cetera, and then training the next-generation workforce and reinvigorating the interest of the youth of America in manufacturing as a well-paid, excellent career.

Why additive manufacturing? As has been shared, it is a disruptive game changer. And game changer is often overused, but I am comfortable with declaring that additive manufacturing absolutely is a game changer, fundamentally because when you change the game, you change the rules, and this has a whole new set of rules.

We have a lot of people come to us and talk about the excitement and their interest in additive manufacturing and say: Ed, I want to get involved in additive manufacturing.

ASME has identified seven different types of additive manufacturing, and I realize when people approach us, it is like asking me, "Hey, Ed, I want to cook dinner. Help me cook dinner." And to be more specific, what heat source are you going to be using, lasers, et cetera? What materials are you going to be using? Are you going to be using polymers or plastics? Are you going to be using metals? Are you going to be using ceramics? Are you going to be using organic tissue? Are you going to be using human tissue?

Then what are you going to do with it? What is for dinner? Are you going to be serving plastic parts, mechanical parts, electronic parts? Food? 3D Systems did a demonstration of printing Oreo cookies for a demonstration that we were involved with. And you can print body parts.

One of the things that excites me is the potential of integrated mechanical and electronic 3D printing devices, and one of our key members, the University of Texas at El Paso, with the W.M. Keck

Center for 3D Innovation, we have recognized them as our first satellite center, broadening our footprint in a very substantial way across the United States.

Our public partners in this adventure are the Department of Defense, the Department of Energy, Department of Commerce, Department of Education, NASA, the National Science Foundation, FAA, and the FDA, and we are strong believers in the power and wisdom of a public-private partnership.

We currently have 163 members. In correcting an era in the printed testimony, we have 55 small businesses, not 85, 43 large businesses, 13 Government partners, 10 nonprofit organizations, and 4 manufacturing extension partners, or MEPs, and they are a very valuable partner in helping doing the technology transition for this.

As of January 2016, we had an $87 million portfolio of research and development. Sample projects, our use of additive manufacturing in the foundry business, led by YoungstownBusiness Incubator, revolutionizing the foundry casting business, making sure it stays on shore, taking out costs, cycle time, and improving product performance.

We also have a project on biomedical devices with the University of Pittsburgh working on optimizing magnesium alloy for bioabsorbable cranial implants.

Applying the partnership model to education, we are doing lots of activities, including a certification program with the Society of Manufacturing Engineers, a fellowship program with the American Society of Mechanical Engineers.

We are partnering with the U.S. Department of Veterans Affairs as part of a Google.org grant to train returning military veterans. We think that is a very important service to the Nation. What better source of expertise and competency to tap, and innovative people as well.

And then we are also revolutionizing STEM education for those that want hands-on learning, making math relevant in what you produce with the capabilities.

Regarding the public-private partnership, its ability to, with cost share as the economic model, we think it is a very wise policy and business practice. With the taxpayers' investment on topics of mutual interest we are almost able to double the taxpayer's money. The industry side is able to maximize their research and development dollars. So it really is in line with the Better Buying Power vision of the Department of Defense to optimize contractor research and development and internal research and development.

And then finally, in closing, quoting a good friend, Steve Welby, the honorable secretary of defense for research and engineering, with this technology, let's disrupt ourselves before others disrupt us. Thank you.

[The prepared statement of Mr. Morris follows:]

Testimony before the Subcommittee on Commerce, Manufacturing, and Trade

Hearing on "Disrupter Series: 3D Printing"

By Ed Morris, Vice President and Director

America Makes – The National Additive Manufacturing Innovation Institute

Operated by the National Center for Defense Manufacturing and Machining

Friday, February 26, 2016

America Makes – The National Additive Manufacturing Innovation Institute

Summary

Additive manufacturing, more popularly known as 3D printing, is disruptive in multiple positive ways:

- It is an incredible fulcrum to reinvigorate the manufacturing economic engine in the United States.
- It can revolutionize STEM education by bring a whole new meaning to "hands-on," from the skills training for engineering and the sciences to the revenue-generating production of new and enhanced products that cannot be made using traditional manufacturing techniques.

America Makes – The National Additive Manufacturing Innovation Institute is a public-private partnership charted to accelerate the use of additive manufacturing through technology development, technology transition, and workforce and educational outreach. A public-private partnership is an essential national policy and business model if the United States is to continue to excel in the evolving, highly competitive global economic environment. A key element in an effective public-private partnership is cost sharing, especially when the national objectives and business risks are too much for industry to bear on its own. When industry and academia provide cost share that matches the public R&D investment, the taxpayer receives double the normal output from the public investment. Industry is able to stay competitive as other nations continue to invest heavily in technologies such as additive manufacturing.

Quoting the Honorable Stephen Welby, Assistant Secretary of Defense for Research and Engineering (ASD(R&E)), "Let's Disrupt Ourselves Before Others Disrupt Us."

3D Printing / Additive Manufacturing – Accelerating the Positive Disruption

Who are we? America Makes is the National Additive Manufacturing Innovation Institute, the national accelerator for additive manufacturing and 3D printing. 3D printing allows for production of never-before-possible products and for producing many existing products quicker and cheaper. The vision for America Makes is to accelerate additive manufacturing innovation to enable widespread adoption by bridging the gap between basic research and technology commercialization. As a public-private partnership, America Makes fosters game-changing collaboration between multiple government agencies and over 160 companies, universities, community colleges, and non-profit organizations. In addition to technology development and commercialization, the core mission includes engaging with small and medium-sized businesses, fostering education initiatives, and conducting STEM outreach to both stimulate job creation and train a highly skilled workforce. America Makes is operated by the National Center for Defense Manufacturing and Machining (NCDMM), a not-for-profit 501(c)(3) company.

Why a Public-Private Partnership for Additive Manufacturing? America Makes exists as a public-private partnership because a combined public and private investment is the most efficient and effective method to enable U.S. federal agencies, industry, and academic institutions to collaborate and coordinate. The public-private partnership is invoked via a Cooperative Agreement with the Department of Defense (DoD) executed through the Air Force Research Laboratory. In addition to the DoD, our federal department and agency partners include the Department of Energy (DoE),

the Department of Commerce (DoC), the Department of Education (DoEd), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the Federal Aviation Administration (FAA), and the Food and Drug Administration (FDA).

Without this joint public and private collaboration and pooling of resources, U.S. companies may suffer tremendous technological disadvantages against global competitors that are receiving significant public investments from their governments. Additive manufacturing was invented in the United States in the early 1980's, and like many U.S. innovations that have a strong impact on a nation's economy and industrial base, the U.S. lost the lead due to Europe's long-term governmental investments to develop and market advanced additive manufacturing printing equipment and materials. Other nations, from China to Singapore, are now focusing their national R&D investments in additive manufacturing technology R&D because of the impact it will have on their manufacturing economic engines.

A key element in an effective public-private partnership is cost sharing, especially when the national objectives and business risks are too much for industry to bear on its own. The value proposition is simple. The public-private partnership model with cost share provides the ability to leverage the investment by the public and private funding sources in areas of mutual specific interest that benefit the nation. When industry and academia provide cost share that matches the public R&D investment through the Cooperative Agreement with America Makes, the taxpayer receives double the normal output from the public investment. That's a strong business case for the public. The public partners further reduce their risk as a result of ready access to a vetted additive manufacturing supply chain network of industry and academic leaders and subject matter experts.

For those doing the work and providing cost share, the ability to spread the cost share across the performing team further reduces their risk and increases their return on investment. This business model aligns perfectly with the Department of Defense's Better Buying Power 3.0 initiative to increase the productivity of industry Independent Research and Development (IR&D) and Contracted Research and Development (CR&D).

To help the U.S. stay competitive, America Makes is creating both face-to-face and online mechanisms for broad-based collaborative efforts to identify capability gaps, solve shared problems, coordinate investments, and share knowledge in 3D printing. With the combined and integrate public and private investments, America Makes is establishing a culture of collaboration that is developing into a strong engine for innovation and technology commercialization in the United States.

What have we accomplished? Since being launched over three years ago in August 2012, America Makes – the National Additive Manufacturing Innovation Institute has taken long strides in achieving its mission. These are a few highlights:

- Established the America Makes Innovation Factory in Youngstown, OH with over 20 additive manufacturing machines entrusted by members, plus collaboration & education workspaces.
- Engaged 163 dues-paying members from industry, academia, and non-profit organizations.
    - 43 Industry Large Business Partners
    - 85 Industry Small Business Partners
    - 38 Academic Partners
    - 13 Government Partners

- 10 Non-Profit Organizations
- 4 Manufacturing Extension Partnership (MEP) Members

- Developed the second version of our member-driven Additive Manufacturing Roadmap that drives the technology investment strategy for America Makes. Roadmapping is accomplished via multiple workshops with our industry, academia, and government partners to identify and prioritize research and development required to meet the needs of our additive manufacturing community and accelerate the use of the technology in the United States.
- Launched and executing a strong portfolio of research and development (R&D) projects that attack the numerous technical challenges and roadblocks hindering the accelerated use of additive manufacturing. With the addition of our 2016 Project Call about to be released to our members, America Makes will soon have a portfolio worth more than $96 million in public and private funds invested in advancing the state-of-the-art in additive manufacturing for the United States. The 58 R&D projects initiated to date address additive manufacturing design, materials, processes, the supplier value chain, and the additive manufacturing genome of modeling and simulation analysis tools.
- Implemented a secure, virtual collaboration section within our website (www.AmericaMakes.US) for America Makes members which links to a repository for project information, including materials and processing data, central to companies being able to design new products to be produced using additive manufacturing.
- Led and supported numerous workforce training and STEM outreach programs, including an Additive Manufacturing Certificate program, providing mentoring and equipment to FIRST Robotics teams, and co-creating the privately-funded "3D Printer in Every School" initiative.

The R&D projects are producing results that are impacting multiple product sectors, from aerospace and defense to life-saving medical applications. Use of additive manufacturing for aerospace products improve performance, reduce cost, and shorten manufacturing lead-times. Few technologies are capable of delivering improvements in all three areas. One project is focused on the use of additive manufacturing in the Foundry industry, reducing the cost and cycle times to produce castings in the United States while also enhancing product performance. This is a critical action to preserve and strengthen the Foundry industry in the United States. One medical project is optimizing the design and manufacture of cranial implants for head injuries using the technology. This takes additive manufacturing from being a game-changer to a life-saver.

Why Additive Manufacturing Workforce and Education?

The balance of this testimony will focus on America Makes' public-private partnerships to accelerate and improve additive manufacturing workforce and education activities across the United States.

Additive manufacturing is one of the fastest-growing manufacturing trends and calls for new ways to educate and train both the current and future workforce, in an industry where change is constant and nearly 3.5 million manufacturing jobs will need to be filled in the next decade. America Makes is working with partners from across industry, academia, non-profit organizations, and the federal, state, and local government levels to build a comprehensive workforce and education roadmap and to support and execute strategic programs and projects that include building knowledge and awareness, fostering hands-on learning, strengthening industrial experience through trainee programs, and building the talent pipeline across sectors and diverse populations.

As part of these efforts, America Makes is focused on a number of activities which includes establishing infrastructure to create project based learning environments, partnering with members to educate

students and train workers in advanced manufacturing skills, identifying and engaging industry to address needs and skills gaps, providing professional education on advanced manufacturing and deploy education activities, programs and certifications, and integrate workforce and education into America Makes Project Calls.

To improve STEM and workforce training, America Makes is focused on partnering across sectors and leveraging community resources including industry, non-profits, and academic partners, including universities and community colleges. The following are a sample of partnerships, programs, and activities underway.

1. The development of Certificate Programs and trainings to expand ***individual knowledge*** of 3D printing and additive manufacturing.

    - SME, in cooperation with the Milwaukee School of Engineering and America Makes, has established a team of advisors who have strategically defined an additive manufacturing body of knowledge. This body of knowledge serves as the basis for an Additive Manufacturing Certificate Program, which includes a review course and an exam. The certificate program is designed to expand knowledge of Additive Manufacturing technologies and helps individuals to validate their knowledge in the field, upgrade knowledge, and stay current with industry standards and obtain a portable career credential in additive.

    - America Makes member, Underwriter Laboratories, has launched its first e-learning module, the Foundations of 3D printing. Geared to those who are new to this

technology, Foundations of 3D Printing is an interactive four-module course that presents comprehensive introductory knowledge of the 3D printing industry.

2. Development of Massive Online Courses (MOOCS) to educate the market on the ***business drivers*** of additive manufacturing.

    - Deloitte University Press and America Makes, in collaboration with Marquette University, Oak Ridge National Laboratory, and 3D Systems created the Massive Open Online Course (MOOC) titled *3D Opportunity: Additive Manufacturing for Business Leaders.* It is the first course of its kind to be offered by a large professional services firm and is designed to help educate the market on the business drivers of additive manufacturing (more popularly known as 3D printing). This free course has reached more than 14,000 individuals to date.

3. Partnerships to build ***internships, fellowships, and apprenticeships*** in the field of additive manufacturing.

    - ASME Fellowship: America Makes has worked with ASME to launch the *America Makes Advanced Manufacturing Fellowship Program*. The fellow participates as part of a public-private team to develop and lead high-level projects in workforce, including technical and strategic planning activities relative to the mission of America Makes. Fellows receive a career-broadening experience in program management, organizational development, and hands-on applied research.

- Robert C. Byrd Institute (RCBI) Apprenticeship Grant: Using a unique apprenticeship program to help train underserved communities learn advanced manufacturing skills such as 3D printing, the Robert C. Byrd Institute for Advanced Flexible Manufacturing is taking their approach to manufacturing education even further. RCBI has partnered with America Makes on a $4.9 million grant from the U.S. Department of Labor to help expand their apprenticeship model, curriculum, and training program guidance. America Makes is working closely with SME and RCBI to share our America Makes core curriculum and is providing advice regarding an appropriate training focus for the pre-apprentice program.

4. Partnerships to train veterans with ***workforce development*** and assistive technology skills.

    - America Makes has partnered with the U.S Department of Veteran Affairs as part of a Google.org grant to develop training for returned military veterans to learn the basics of creating personalized assistive technologies using 3D printing, rapid prototyping, and scanning technologies. These skills will be useful as veterans return to an increasingly digital job workforce. This pilot program will teach and train veterans on skills and knowledge associated with rapid prototyping, including design thinking + additive manufacturing.

      The goals of this program are four-fold:

        - Develop community-based resources to amplify VA's existing capacity surrounding the development of personalized assistive technologies for veterans faced with disabilities.

- Teach and train 15 veterans in the community on 21st century skills, such as Human-Centered Design + additive manufacturing, to help them obtain future job opportunities and reintegrate into their community. The training element of this program will be developed in collaboration with 3D Universal and Oak Ridge National Labs.
- Lay the foundations for a new educational and workforce development program model to scale to other communities with a curriculum, playbook, and suggested collaborations with local stakeholders to develop assistive technologies and assist with workforce development efforts at the local level.
- Enable development and scaling of assistive technology solutions through financial support from Google.org and open sourcing of designs through the National Institute of Health (NIH) 3D Print Exchange for all to use in their own communities and settings.

5. Partnerships to focus on bringing additive manufacturing to ***community colleges and vocational and tech education.***

- America Makes and Westmoreland County Community College (WCCC) are working in collaboration as part of an Alcoa Foundation grant to ensure young people have the skills they need to compete in a 21st century economy, and to align these skills with the growing demands of American employers, with a particular focus in additive manufacturing and 3D printing for community college students and vocational/tech education teachers in Pennsylvania, specifically in the Westmoreland and Indiana School Districts.

The goals of this project are two-fold. One is to build job-ready skills around additive manufacturing in students attending community colleges, and the second is to train teachers and educators in grades 9-12 vocational/tech education, so they can bring similar courses to their students through an initiative called *Building Manufacturing Skills for the 21st Century*. This program will use a blended learning approach by combining hands-on work with theory-based education applied to additive manufacturing. Additive manufacturing enables production of complex and customized designed parts by adding layer upon layer of material, whether plastic, metal, or even human tissue. This technology is being used to fabricate end use products in aircraft, dental restorations, medical implants, automobiles, and even food and fashion.

Specifically, this partnership includes the development of a 24-Hour Additive Manufacturing Curriculum. Developed by Westmoreland County Community College and built in partnership with 3D Systems, this curriculum will be aligned with, co-created, and reviewed by key leaders in education and manufacturing. The curriculum will include the following objectives:

- Introduce students to 3D Printing, 3D Scanning, and 3D Software Technology.
- Introduce students to the concept of reverse engineering and how it is used in Industry.
- Support teachers/educators to bring this technology to their 9-12/Vocational Tech Education Classroom.
- Develop a Community College Course for general population/community as part of the Westmoreland County Community College.

- Train 40 teachers in PA from 9-12/Vocational and Tech Education. In order to leverage this class and bring it to vocational/tech education and 9-12 grades, 40 teachers in PA will take the WCCC class, so that they are trained and comfortable with both the equipment & software.

Ultimately this program works to achieve the following goals:

- Provide students with opportunities to learn 3D design, 3D scanning, and 3D printing in the context of industries like aerospace, automotive, and biomedical, and ensure that the next generation has the skills they need to compete in the 21st century economy.
- Help to transform digital literacy in the classroom, through providing high school/vocational and tech education teachers with training, that they can then scale and bring it into their classrooms.

Conclusion

In closing, additive manufacturing is a game-changer because it brings a whole new set of rules to multiple industry sectors, from aerospace and defense solutions to life-saving medical applications. If you change the rules, you change the game. It is also an incredibly powerful teaching tool to reinvigorate STEM education in the United States. Combined, additive manufacturing is playing a critical role in ensuring a robust manufacturing-driven economy in the decades ahead. But it must be done in a public-private partnership if the United States is to continue to excel in the evolving, highly competitive global economic environment.

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About America Makes

America Makes is the National Additive Manufacturing Innovation Institute. As the national accelerator for additive manufacturing (AM) and 3D printing (3DP), America Makes is the nation's leading and collaborative partner in AM and 3DP technology research, discovery, creation, and innovation. Structured as a public-private partnership with member organizations from industry, academia, government, non-government agencies, and workforce and economic development resources, we are working together to innovate and accelerate AM and 3DP to increase our nation's global manufacturing competitiveness. Based in Youngstown, Ohio, America Makes is the first institute for up to 45 manufacturing innovation institutes to follow and is driven by the National Center for Defense Manufacturing and Machining (NCDMM). For more information about America Makes, visit http://americamakes.us.

About NCDMM

The NCDMM delivers optimized manufacturing solutions that enhance the quality, affordability, maintainability, and rapid deployment of existing and yet-to-be developed defense systems. This is accomplished through collaboration with government, industry, and academic organizations to promote the implementation of best practices to key stakeholders through the development and delivery of disciplined training, advanced technologies, and methodologies. For additional information, visit the NCDMM at ncdmm.org.

Mr. BURGESS. The Chair thanks the gentleman.

Dr. Herderick, you are recognized for 5 minutes. Just summarize your opening statement, please.

STATEMENT OF EDWARD D. HERDERICK

Mr. HERDERICK. Thank you. Chairman Burgess, Vice Chairman Lance, Ranking Member Schakowsky, and members of the committee, it is a privilege to share GE's thoughts on 3D printing, which represents the larger digital industrial revolution happening in the U.S. and globally.

Today, a designer can create a computer-aided design model of a part and digitally transmit it to a 3D printer to be directly manufactured. Increasingly, new designs and processes like this are being connected and managed through a digital thread where the freedom of design and manufacturing seemingly has no limits. One of GE's engineering leaders appropriately captured it when she said: Complexity is free.

My name is Dr. Ed Herderick, and I am the additive technologies leader for GE helping to spread the application of additive technology across GE's industrial portfolio. This portfolio spans across industries that build, move, power, transport, and cure the world, from jet engines and power-generation machines, to locomotives, medical imaging systems, and more.

The emergence of 3D printing and additive technologies in industry has been both sudden and disruptive. Recently, Boeing and Airbus conducted the first flight tests for their 737 MAX airplane and A320neo single-aisle jets with GE LEAP engines.

LEAP is the world's first jet engine to include 3D-printed fuel nozzles, one of which I have here on the table, which as the engine's fuel injector, mixing fuel and air in precise ways to achieve maximum fuel efficiency and lower emissions. Using metal printing, the fuel nozzles are more fuel efficient, lighter weight, and more durable compared to those made with conventional technologies.

The production of 3D-printed metal parts in jet engines would have been almost unheard of even a decade ago. Today, we are asking what else can be printed in the engine to drive performance even higher. As it is, GE Aviation will be producing 35,000 printed fuel nozzles per year at the world's first mass additive production facility in Auburn, Alabama. By 2020, we will have produced more than 100,000 metal-printed fuel nozzles.

This success of industrial implementation of additive technology in the aerospace industry is paving the way for broader applications in other industries. GE's use of additive technologies in aviation is only the tipping point of an exciting transformation underway across our 400-plus factories. By 2025, we expect additive manufacturing methods will be used in the design and manufacture of more than 20 percent of GE's new product concepts.

Our efforts in additive are part of a much broader initiative to build a digital thread through manufacturing that transforms our factories into "Brilliant Factories." It is through this digital thread where additive technologies can truly emerge and realize their full potential for industries of all kinds.

In many ways, the excitement and emphasis on additive manufacturing of metals and industrial materials is the product of a more than 20-year research odyssey. As early as 1993, researchers at GE Global Research demonstrated the feasibility for binderless sintering of metal powders.

It is interesting to note the development and material advancement between then and now. In 1993, the laser used had only 7.5 watts of power, a scanning speed of 2 millimeters per second, and produced parts that were 30 percent dense. Today, we are using lasers with 200 to 1,000 watts of power, scanning speeds of 1,000 millimeters per second, and produce parts that are greater than 99.9 percent dense straight out of the box.

Further, when implemented with care, the performance of additively produced metal parts today meets and even exceeds that of standard casting techniques, and this is a critical point. I cannot emphasize enough the importance of understanding the physical metallurgy in order to produce this high-quality repeatable performance as the materials' properties are determined during the printing process.

Manufacturers have had centuries to understand the physical properties of materials that have been traditionally milled or machined into the desired shape. With additive, and metals in particular, we have been working for 20 years. Fortunately, GE, through its Global Research Center, is home to some of the world's foremost experts in materials and additive techniques to help us make these evaluations.

I would like to highlight a particular example where GE printed a miniaturized version of a steam turbine rotor to test a new idea GE researchers have for reducing the cost of water desalination. The rotor, roughly 6 inches long, is being used to demonstrate cost-effective water and salt separation. In that case, metal printing empowered the team to design something that could not be made in any other way and has the potential to dramatically improve the energy efficiency for this critical water desalinization process.

In order to accelerate new applications like this one, GE has built a new facility in Pittsburgh, Pennsylvania, dedicated solely to 3D printing called the Center for Additive Technology Advancement. And that was an ARPA—E program and partnership.

So I would like to highlight some of our work and the critical importance of building a robust ecosystem in additive technologies across the U.S. We are proud to be a partner of and applaud the America Makes National Additive Manufacturing Innovation Institute in Youngstown, Ohio, which has been a leader in building this ecosystem of manufacturers, machine makers, and other key stakeholders in the additive supply chain. As we go forward, GE will continue to look for ways to strengthen the additive ecosystem here in the U.S.

In closing, additive manufacturing is a transformative technology that is opening up new frontiers and is an important tool in realizing GE's "Brilliant Factory" vision. It is and will have far-reaching impacts that accelerate the introduction of new high-performance products that will support global infrastructure for years to come.

Thank you, and I look forward to your questions.

[The prepared statement of Dr. Herderick follows:]

Opening Remarks for House Energy and Commerce Subcommittee Hearing

Edward D. Herderick
Additive Technologies Leader
GE Corporate Supply Chain and Operations
[redacted]

Chairman Burgess, Vice Chairman Lance, Ranking Member Schakowsky and members of the Committee, it is a privilege to share GE's thoughts on 3D printing, which represents a larger digital industrial revolution happening in the US and globally. Today, a designer can create a computer-aided design model of a part and digitally transmit it to a 3D printer to be directly manufactured. Increasingly, new designs and processes like this are being connected and managed through a digital thread where the freedom of design and manufacturing seemingly has no limits. One of GE's engineering leaders appropriately captured it when she said, "Complexity is free."

My name is Ed Herderick, and I am the Additive Technologies Leader for GE helping to spread the application of additive technologies across GE's industrial portfolio. This portfolio spans across industries that build, move, power, transport and cure the world, from jet engines and power generation machines to locomotives, medical imaging systems and more.

The emergence of 3D printing and additive technologies in industry has been both sudden and disruptive. Recently, Boeing and Airbus conducted the first flight tests for their 737 MAX airplane and A320neo single aisle jets with GE LEAP engines. LEAP is the world's first jet engine to include 3D printed fuel nozzles, which as the engine's "fuel injector," mixing fuel and air in precise ways to achieve maximum fuel efficiency and lower emissions. Using metal printing, the fuel nozzles are more fuel efficient, lighter weight, and more durable compared to those made with conventional technologies.

The production of 3D printed metal parts in jet engines would have been almost unheard of even a decade ago. Today, we are asking what else can be printed in the engine to drive performance even higher. As it is, GE Aviation will be producing 35,000 printed fuel nozzles per year at the world's first mass additive production facility in Auburn, Alabama. By 2020, we will have produced more than 100,000 metal printed fuel nozzles. This success of

industrial implementation of additive technology in the aerospace industry is paving the way for broader applications in other industries.

GE's use of additive technologies in Aviation is only the tipping point of an exciting transformation underway across our 400+ factories. By 2025, we expect additive manufacturing methods will be used in the design and manufacture of more than 20% of GE's new product concepts. Our efforts in additive are part of a much broader initiative to build a digital thread through manufacturing that transform our factories into "Brilliant Factories." It is through the digital thread where additive technologies can truly emerge and realize their full potential for industries of all kinds.

Let me begin by introducing a bit of background on what I mean by additive manufacturing. For many additive manufacturing is synonymous with 3D printing. It's actually much more. Within GE, it involves a group of seven technologies that grow parts layer-by-layer from the bottom up from digital files. Processes such as cold spray, which spray metal powders at supersonic speeds, or direct write, which deposit liquid material through a stylus to print components like sensors, represent other ways of "building up"
parts. Moreover, additive manufacturing itself is much more than just printing parts. GE uses additive throughout its manufacturing operations, from rapid prototyping and testing new designs to developing new tooling.

My testimony today is focused on one of those technologies, Laser Powder Bed Fusion, which is the most widely used of the metal printing technologies at GE. This technology uses powdered metal as the input material. The metal powder looks similar to silver colored metal flour and is engineered in both size and shape specifically for printing. The powder is encompassed in a box filled with an inert gas, such as nitrogen, and is melted in patterns to form parts using an industrial fiber laser. The parts are built on a metal plate in layers of 1 to 3 thousandths of an inch or about the thickness of a human hair. The machines themselves are about the size of two refrigerators side by side.

In many ways, the excitement and emphasis on additive manufacturing of metals and industrial materials is the product of a more than 20 year research odyssey. As early as 1993, researchers at GE Global Research demonstrated the feasibility for binderless sintering of metal powders. It's interesting to note the process and material advancement between then and now. In 1993 the laser used had 7.5 Watts of power, a scanning speed of 2 millimeters per second, and produced parts that were 30% dense. Today, we are using lasers with 200 to 1,000 Watts of power, scanning speeds of 1,000 millimeters per second, and produce parts that are greater than 99.9% density straight out of the box. Further, when implemented with care, the performance of additively produced metals parts today meets and even exceeds that of standard casting techniques. And this is a critical point.

I cannot emphasize enough the importance of understanding the physical metallurgy in order to produce this high quality, repeatable performance as the material properties are determined during the printing process. Manufacturers have had centuries to understand the physical properties of materials that traditionally have been milled or machined into the desired shape. With additive, and metals in particular, we have had only 20 years. Fortunately, GE, through its Global Research Center, is home to some of the world's foremost experts in materials and in additive techniques to help us make these evaluations.

As I mentioned, GE has expanded its thinking and application on where additive technologies can be applied across our businesses. I am excited to share a few more examples with you. In fact, one is part of an ongoing project we have with the Advanced Research Projects Agency for Energy (ARPA-E), wherewe have 3D printed a miniaturized version of a GE steam turbine rotor to test a new idea GE researchers have for reducing the cost of water desalination.. The rotor, roughly 6 inches long, is being used to demonstrate cost effective water and salt separation. In that case, metal printing empowered the team to design something that could not be made any other way and has the potential to dramatically improve the energy efficiency for water desalinization. In order to accelerate new applications like this one, GE has built a new facility in Pittsburgh, Pennsylvania dedicated solely to 3D printing called the Center for Additive Technology Advancement.

We are also investing in small businesses through GE Ventures. One example where we have made a strategic investment is a company called Optomec based in Albuquerque, New Mexico. A key area of collaboration is 3D Sensors that are directly printed onto high-value components. Such tightly integrated sensors provide critical input to structural health and have the potential to substantially reduce the life cycle cost of complex mechanical systems

GE's initiatives with ARPA-E and through our Ventures business highlight the critical importance of building a robust ecosystem in additive technologies across the US. We're proud to be a partner of and applaud the America Makes Additive Innovation Institute in Youngstown, Ohio, which has been a leader in building this ecosystem of manufacturers, machine makers and other key stakeholders in the additive supply chain. GE also recently joined the 3MF Consortium. Based in Massachusetts, this Consortium is bringing big companies like GE and Microsoft together with machine makers such 3D Systems and Stratasys and design software makers such as Autodesk to standardize file formats around 3D printing. As we go forward, GE will continue to look for ways to strengthen the additive ecosystem here in the US.

In closing, additive manufacturing is a transformative technology that is opening up new frontiers in manufacturing and is an important tool in realizing GE's Brilliant Factory vision. It is and will have far reaching impacts that accelerate the introduction of new, high performance products that will support global infrastructure for years to come. Thank you, and I look forward to your questions.

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Mr. BURGESS. The Chair thanks the gentleman, thanks all of our witnesses for your compelling testimony this morning. Thanks for all you are doing for the revitalization for manufacturing in America, and we appreciate your efforts in that regard.

Dr. Herderick, you talked about the experience you have had with manufacturing things for years, and now you have moved into this new realm. So I suspect there were significant challenges for, like, the quality control folks who assured that the device in question was going to stand up under the heat and pressure of a jet engine or a pump or whatever you were building.

I suspect that has been an ongoing process and one that has developed sort of simultaneously with the technology. Is that a correct assumption?

Dr. HERDERICK. It is. Yes, so it has been a many-year journey. And I think what GE brings to this is our knowledge of commercializing other advanced technologies, like advanced casting techniques, welding techniques, and the like. And so we use the same process methodology of really fundamentally understanding the science at our research center, as I mentioned, and then working closely with our partners to really understand how these products perform in the field.

Mr. BURGESS. But you are literally building airplane parts out of pixie dust and putting them into planes that we are all going to fly home later today.

Dr. HERDERICK. Well, it is advanced metal powder that looks like metal flour, so I suppose you could paraphrase to call it pixie dust, but it is very highly engineered pixie dust.

Mr. BURGESS. That is reassuring.

Now, Mr. Orringer, let me just ask you, well, your technology, you talked about it in your testimony, invented your company in the United States. The patent system in the United States, despite challenges, is one that is the envy of the world. But then you intersect with the regulatory side of the world. So sometimes things that are invented here but then subsequent manufacturing tends to go other places in the world. So is that something that you all have encountered?

Mr. ORRINGER. So I am a little bit at a disadvantage because if I say anything wrong my lawyers are going to come down on me pretty hard.

Mr. BURGESS. This subcommittee is so genteel. There is no oath given.

Mr. ORRINGER. I am not worried about you.

Mr. BURGESS. There is no oath given, no lawyers backing up the panel.

Mr. ORRINGER. Let's just say you are absolutely right. So as I said, this technology has been around for 30 years. We have invented many of the technologies that we have been discussing here today, and we have been acquiring a lot of these companies along the way as well.

In spite of it being 30 years old, it has become a little bit of the Wild West. And there are constantly new innovations, there are patents that seem to be very similar to patents that were filed previously, and we have to be vigilant. And, fortunately, we do have

a very good, close relationship with the U.S. Patent and Trade Office. We do work very closely with regulators.

There are always going to be issues, particularly when you compare our system with a system overseas, and that is where we are really challenged, and we do appreciate the assistance that the Government is providing us as we navigate these waters right now.

Mr. BURGESS. Well, I want you to consider this subcommittee as your subcommittee, and the interaction that we have initiated today, I want it to be an ongoing dialogue. Because to the extent possible we want to remove barriers for you, we don't want the invention to happen here and then the manufacturing occur somewhere else. We want these jobs in the United States of America. We want to make America great again. Could I say it any more succinctly?

Mr. ORRINGER. I am not going to touch that.

I will say to that point, I very much appreciate that, and I will say that what has actually been quite exciting coming here, I spent most of my career in the Federal Government and only have transitioned to the private sector 2 years ago. And I will tell you, coming to this company and seeing what we are doing in terms of U.S. jobs is phenomenal.

We just acquired two European companies, a French company and a Belgian company. These are companies that have been honing the craft of metal additive manufacturing. And we are now seeing an insourcing, thanks to my company, not only in terms of protection, but R&D. We are actually moving these jobs over here.

And it is actually thanks in part to projects that we are doing with America Makes. I am actually funding an aerospace and defense project. We have started to build up a laboratory in Penn State. And it is thanks to the good work of Ed and his colleagues, as well as other folks that we are teamed with, that is seeing this technology not sit still but continue to innovate, and we will certainly stay engaged with you as we navigate these waters.

Mr. BURGESS. And I appreciate that. You are two of the most highly regulated industries, medicine/healthcare and the aerospace industry.

Mr. Morris, did you want to add something?

Mr. MORRIS. Yes. In regard to the global economic competition we find ourselves in, it is absolutely true that although the technology of additive manufacturing was invented in the United States, we lost the lead, and generally the sense is the Europeans are ahead by about 5 years because they doubled down with national investments in their areas, and they are the major source of the materials and the 3D printing devices. Although in the United States companies such as 3D Systems are coming on very rapidly and regaining the lead for the United States, which we think is crucial.

I think this really comes into focus, the importance of a public-private partnership as a wise policy for a nation in this global economic competition we find ourselves, and it is a good business model for the taxpayer and for the companies and academia, for that matter.

Mr. BURGESS. Very well. The Chair thanks the gentleman.

My time has expired. I recognize the ranking member of the subcommittee, Ms. Schakowsky of Illinois, for 5 minutes for questions, please.

Ms. SCHAKOWSKY. Thank you, Mr. Chairman.

I encountered 3D printing in 2013. We had a manufacturing showcase, and Congressman John Sarbanes brought in a business from his district, Direct Dimensions, and they took a picture, three or four, and made this 3D print, a bust of me in plastic. It was very interesting and a little strange. But I did save it.

I want to say this is part of our series, as I am sure our chairman said, of our Disrupter Series, and what we are hearing today are the wonders of this and the positive.

And I just want to say before I ask questions along those lines, that these technologies can be in the hands of all kinds of people as we go forward. And I hope, Mr. Chairman, that we will also have a hearing on what are the things that we ought to watch out for.

I know that Congresswoman Clarke raised the issue of the ability to produce perhaps small arms. But who knows? And so I think we ought to be looking ahead to and thinking about if there are threats to our country because of these kinds of new technologies and in the wrong hands, not only through our concerns about competition around the world and making sure that we can advance making an America, but actual threats.

But I wanted to focus on the positive too. At Northwestern University, which is in my district in Evanston, Illinois, researchers are pioneering biocompatible inks made of graphene that are used to 3D print scaffolding for tissue transplants and regeneration. Very exciting. These graphene structures can stimulate cell regeneration and also are cost effective.

So, Mr. Orringer, could these kinds of cutting-edge treatments become more widely accessible through the use of 3D printers?

Mr. ORRINGER. Yes. Actually, I just returned from your district. I was just there last week.

Ms. SCHAKOWSKY. OK.

Mr. ORRINGER. I talked to a couple of folks about Northwestern's interest in metal. And I will tell you, the Chicago area is booming in this area, very competitive area for this technology, and it is very important that we continue to innovate there and incubate that technology.

On the bio side, I will tell you, there is a lot of fact and fiction and aspiration. To answer your question, I think you summed it up quite well. There is sort of the short term, there is a lot that can be done in scaffolding, and it is being done currently, and I would say we are about 1 to 2 years away from seeing this matured sufficiently where it is going to become as commonplace as some of the other methodologies I discussed.

On the other side, our folks in our medical modeling department indicated that we are still a few years away from actually seeing a viable process for some of the other bioprintable inks. But the research is being done. Actually we do a feasible path forward. We are watching a lot happen in this marketplace. There are a lot of exciting new companies that are coming online in this space, and we would encourage that technology continue to flourish.

The Government itself has a role to play. We have been talking to NIH about this particular issue to see if there are ways we can work with them in terms of spurring innovation in this area.

Ms. SCHAKOWSKY. So you indicated some fairly early benefits here too. So at what point do you think we will be able to see real savings for patients, and are we doing what we need to do now to make that occur?

Mr. ORRINGER. Well, as I highlighted in my opening statement, 3D printing has long been providing strong value to patients, not only in the hearing aid, where we are making 99.5 percent of hearing aids through 3D printing, or Invisalign, but in the medical modeling and in the implant process as well.

It is literally saving lives. We were talking about this early before the hearing. We charge patients about $100 a minute in the operating theater.

So if you can reduce that time by rehearsal, by using CT scans, 3D printing, the model, and then practicing that surgery over and over again, and then also 3D printing surgical guides, which are essentially stencils that you place on a patient, reducing the amount of improvisation to zero, then you are literally going to be saving lives, enhancing precision, and saving money.

And so I can tell you that we have done tens of thousands of these procedures, and we are seeing a lot of breakthroughs.

In terms of the scaffolding, there is a lot of investment in this arena right now. There is a lot of promise. And the Government is well involved as well, not only from the NIH, but in the Department of Defense, the United States Navy, Walter Reed National Medical Center. There is a lot of work being done here, and I think we are not too far away from some active clinical trials.

Ms. SCHAKOWSKY. Great. Maybe in another round I could ask Mr. Morris how America Makes works in this health space.

Thank you.

Mr. BURGESS. The gentlelady yields back. The Chair thanks the gentlelady, recognizes the gentleman from Kentucky, Mr. Guthrie, 5 minutes for questions, please.

Mr. GUTHRIE. Thank you very much.

It is great to have everybody here. What an interesting series we have had. And as I really grasp technology when I was in grad school in the mid-1990s, not even that long ago, and it just really disrupted the typewriter and the calculator industry because we did the same thing that they were already doing, just did it more efficient. I think also it disrupted the wite-out industry, when I got to go on a word processor, didn't have to use it anymore. But it really just already took what we were doing and just made it better.

And what is happening now is you are actually taking this technology and just doing things we could never do before. It is amazing in the body parts and the replacement, you couldn't do those vertebra probably in any other type of manufacture.

I have a manufacturing background, and we take blocks of steel and make dyes out of it. We whittle it down, for lack of a better term. That is actually what we do, just computer-controlled machines. We are now creating stuff by printing it. By being additive, I hope it doesn't replace what we do, but it certainly enhances the

precision of what you can do in specific things. So it is fascinating to be here.

I am going focus with UPS. Their Worldport is just outside of my district. But a lot of your employees and a lot of your customers are in my district, Zappos shoes, Bestbuy.com, and Geek Squad, which is a pretty interesting place to go. They don't have a plant manager. They have a mayor. And they don't have community leaders. They have ambassadors. So it is just an interesting business concept, but great, great people to be around.

But a lot of it is based on supply chain. I know a lot of us think of UPS as—and you said it in kind of your opening statement—the brown trucks and the airplanes that are flying in and out of Louisville. But I am more interested in what UPS really does. You talked about it a little bit. I would just give you some time to elaborate on how UPS actually helps small businesses with supply chain management to build their businesses and how 3D printing is a big part of that mission.

Mr. AMLING. Yes. Thank you very much.

So UPS is more than a package delivery company. We are a network company. We are not a manufacturer. But we are a network company. We are a problem solver. And so we see 3D printing as another tool in the bag to make businesses more efficient and to help them expand. So that is what the small businesses, it is what the UPS store is all about, in helping small businesses grow.

So when we put 3D printers in the UPS stores, one of the things small businesses have to do, if they have a new product idea, is to design a prototype. Prior to 3D printing, that is an arduous task, right. You have got to create a model. Sometimes that model is produced outside of the U.S. and shipped back. Now we are giving them the opportunity to produce that model and do rapid prototyping right in their home city.

I have an example of a gentleman that we highlighted during our 3D Printing Week named Caleb Kraft. And what he did was he is creating supplements to gaming controls so people with disabilities can play the game. And because people have different disabilities, everyone is different. Can you imagine how difficult that would be before 3D printing?

That is one of the things. We are unleashing innovation. And so that is the small customers. We are seeing a lot of hobbyists, small businesses, and designers using the UPS stores.

We have now more of an industrial-grade 3D printing operation in our Louisville supply chain headquarters, and that is being used by designers, but it is also being used by big manufacturers that have these service part networks, and they need to have on-demand parts. And so we are allowing them to order parts from us and be delivered anywhere in the country.

Mr. GUTHRIE. I have just about a minute. I just want to ask you a couple of more questions.

Mr. AMLING. Yes.

Mr. GUTHRIE. I will ask them both and then let you answer.

So where do you see the most demand for 3D printing today and where do you see it in 3 to 5 years? And what policies should we consider, what are important for us to consider as you see the de-

mand for 3D printing and where it is going? And what can Congress do to help or not help—or get out of way, I guess?

Mr. AMLING. So great. So right now this is what we are seeing. We are seeing a lot of rapid prototyping. That is kind of the application we are seeing the most. We are also seeing a lot of small batch production runs. So even large manufacturers, if they are only printing or need to produce 500 or 1,000 of a certain item, it is actually less expensive right now to do it via 3D printing. And we are all about efficiency, and that is what they are doing.

Now, 5 years out, I wish I had a crystal ball, but what we see is we see more customized products, right, that are tailored to the specific needs of the individual, and 3D printing can allow that to happen. We think that is a little further out, but right now we see definitely on-demand parts in prototypes.

In terms of legislation, again, UPS is a network, UPS is a global network. Right now we are only doing 3D printing in the United States. Eventually, just like we have helped businesses by connecting a global network with our transportation, the plan is to do that with 3D printing. And so as that happens, there are going to be legislative issues that arise that will need to be addressed to keep that going because we know that the more we can promote global commerce and trade, it is good for everybody.

Mr. GUTHRIE. Thank you. Yield back.

Mr. BURGESS. The Chair thanks the gentleman. The gentleman yields back.

The Chair recognizes Ms. Clarke from New York, 5 minutes for your questions, please.

Ms. CLARKE. I thank you, Mr. Chairman.

I thank our panelists today. Very stimulating conversation. It is great to hear all of the innovation that is taking place, and the sky is the limit as far as I see it.

I would like to focus on access for underrepresented communities. This has been one of the focus issues that are especially important to me, using the emerging 3D printing industry as a unique means of empowering and including entrepreneurs from underserved and minority communities, because startups costs are lower, flexible, customization is easier, 3D printers offer advantages and opportunities to small businesses and new entrepreneurs entering the market.

Still, huge diversity gaps remain in the technology manufacturing space. So to harness the true potential of 3D printing, I think it is important to commit to eliminating obstacles to sort of equitable and to promoting initiatives that I believe could close this gap.

You, Mr. Orringer, spoke about a relationship that was established with Penn State. I want to drill down a little bit and talk about perhaps colleges and universities in the HBCU system and the HSI system and community colleges.

And then, Mr. Amling, you spoke to the small business advantage as well.

So, Mr. Morris, my first question goes to you. What kind of outreach does America Makes do to communities that are underrepresented in the tech world, including minority, low-income, and disabled workers?

Mr. MORRIS. Thank you. Excellent question. That is one of the key reasons why the University of Texas, El Paso, was so attracted to us. Not only are they a leader in developing the technology of additive manufacturing, but also in deploying it in their community with a heavy U.S. Mexican population, economically handicapped. And we want to partner deeper with them to be able to help them continue and then expand their technology transitions, again more education in that area, and spawn new products, et cetera.

Tied to that also is the vision that we have of getting printers in every school in the United States. I was certainly taken aback last year when China announced an intent to put 400,000 printers in every one of their elementary schools. We should be doing the same thing and proceeding up the chain for more than just the elementary schools. That is the time to catch the youth in America, get them excited in careers in making things.

And in our context, when we talk about additive manufacturing, it is a system of systems of design, manufacturing, inspection, production, et cetera. So it is all of these different well-paid, good careers, long-term careers. Catching the youth in America no matter where they are, no matter who they are, I think is pivotal for the United States and is an important step forward.

Ms. CLARKE. Can you speak to some of the common challenges that entrepreneurs from underrepresented communities may face when beginning to incorporate 3D printing into their own small businesses?

Mr. MORRIS. What we are finding as small companies come into America Makes as members, and we operate as a community of practice openly sharing, and we operate in this middle ground of precompetitive activities, when the small companies are able to rub shoulders with companies like 3D Systems, Rockwell Collins, Lockheed Martin, Northrop Grumman, et cetera, they develop relationships. So one of our small companies, rp+m in Cleveland, has benefited from that relationship and is now doing contracted work for them.

So building this community, we are very focused on the additive manufacturing supply chain ecosystem: How do we define that, how do we focus it in regional areas? We are doing some pretty incredible things in our region in northeast Ohio and in southwest Pennsylvania trying to flesh out, define that ecosystem, and energize it for all of the communities, and with a focus on those that are most urgently needing that economic boost.

Ms. CLARKE. Very well.

Mr. Orringer, I saw you nodding a bit there and smiling. Do you want to share your thoughts?

Mr. ORRINGER. Well, sure. As we were talking about education, I was just reminded, when I started working for this company, I came home with a little 3D printer and a 3D scanner. And I have a 5-year-old at home who is more advanced technologically than I am. My wife is a surgeon, so she came home from a long day performing surgery, fell asleep watching TV. My daughter scanned her head, produced a model not too different from that, and she is 5 years old. And I was blown away, because I still hadn't figured out how to turn the darn thing on.

And if you can see what happens when we bring these things into schools, it is not about 3D printing. 3D printing is a means to an end, and that is what we need to understand.

What I think about, I think about this in terms of digital literacy, and this is really critically important, particularly in underserved areas. We need to make sure people have a full sense of what it means to be part of the digital economy.

So rather than focusing on getting expensive 3D printers into small businesses, what we really should be doing is making sure they have access to the digital tools, different kinds of CAD, computer-aided design technologies, training in this kind of technology.

We can find ways to give them access to machines, whether it is through great companies like UPS. We have similar programs. We have a company called Quickparts that does on-demand printing. You send us the CAD, we will print out the parts.

It is not about getting the 3D printer necessarily to those entrepreneurs. We actually are able to reduce the logistical footprint for folks. And now we are digitizing things. You don't even need to have that.

So I think the task is important. I don't think it is as difficult as it could be, and there are institutions like America Makes and others that are doing some, but we need to do more. We have talked a little bit about our outreach to the veterans community. We have done a lot with Walter Reed and the Veterans Affairs Administration. But again, there needs to be more in this space, and we would love to talk to the committee and figure out ways to catalyze more of this.

Dr. HERDERICK. Actually, if I may add to that.

Mr. BURGESS. Yes, please.

Dr. HERDERICK. Just briefly.

Mr. BURGESS. Sure.

Dr. HERDERICK. I think you made some great points. And I think what is really exciting about 3D printing is it is just such a transformational educational technology for getting people into manufacturing, and it has really just gotten into the public consciousness.

And I was actually with a GE Volunteers group in the Bronx. We did an outreach, young entrepreneurs workshop with some students, middle school and junior high school students. And what was amazing was half the students, they were coming up with ideas to 3D print different consumer parts for iPods and things. And when we go out and do these GE Volunteers outreach activities, I am doing things like taking fuel nozzles, taking manufactured components, we take 3D printers into schools in different workshops and things.

It is this tool to get people hands-on with manufacturing in a way that we couldn't do with casting or welding. So it is really a gateway to get them into these great entrepreneurial fields and these great careers. It just gets me really, really excited.

Mr. MORRIS. Very quickly. We do some summer camps, and one particular summer camp was 7-through-10-year-olds. And one of the exercises was to take the students into a little kiva round hut, white board, and they drew cookie cutters. And one minority student drew a nice little figure cookie cutter. He then took it is over to the desktop 3D printer and made the cookie cutter. And we have

got a picture of him, you know, look, mom, this is what I thought, this is what I designed, this is what I manufactured, here is a cookie cutter for you.

Mr. BURGESS. The Chair thanks the gentlelady. The gentlelady yields back.

The Chair recognizes the gentleman from New Jersey, Mr. Lance, 5 minutes for your questions, please.

Mr. LANCE. Thank you, Mr. Chairman. A very interesting hearing.

Mr. Orringer, balancing health and safety is obviously an important mission for medical device manufacturers and Federal regulators alike. What steps are the Federal regulators taking in order to educate themselves and the public about 3D-printed surgical implants? Has this approach been proactive? And what else, in your judgment, could be done?

Mr. ORRINGER. Yes, sir. Thank you so much for this question.

I have to say, and it is not just because I am a former Federal bureaucrat, we have been actually pretty pleased with the engagement that the Food and Drug Administration and others have shown. They actually held a workshop in October 2014 on their Silver Spring campus. They invited companies not only from the United States, but from all over the world, to have this dialogue, and it was an all-day affair.

The FDA said they were in receiving mode. They wanted to hear what the concerns were from us about regulation, what the concerns were for us in terms of barriers for innovation, are we any different from any other technology when it comes to regulation. And I think in the end, the conclusion was no, we are one tool in a toolbox. You have digital tools, you have means for designing things, which is the CAD package, and you have different ways for actually executing.

So I think one of the challenges we need to stay on top of is folks' attempts to redefine this technology as something that is extraordinarily different. We are not making Star Trek replicators here. These are very important tools, they have their uses. They also have their limits.

One of the things I sort of alluded to in my statement, though, was concern about the inability for the pay codes to keep pace with innovation. So right now we are innovating doing unique surgical processes, we are saving a lot of money for the health system overall. But the truth is there are no insurance pay codes that can tell the patient this is how much it really costs.

So what is actually happening is we are saving money, but the insurance companies, whether it is Medicaid, Medicare, or private insurance, don't have a means to code what that procedure is. And so there is actually a bit of a margin here. And we would love to engage the folks at CMS, Medicare, Medicaid, or others to ensure that we are actually able to make a fair process and bring that up to standard.

Because right now, as you know, sometimes Government regulation is a little slow, sometimes standards can be a letter slow to implement. We really need to get this right, because we are not really realizing all the potential for this.

Mr. LANCE. I trust those at Medicare and Medicaid and CMS will be monitoring this hearing, because obviously we need those codes for the reasons you have suggested.

Mr. Morris, you wish to comment?

Mr. MORRIS. I personally attended that workshop by FDA in 2014, and I found it intriguing. My background is aerospace and defense, and as I was sitting through the different presentations on medical applications, I found myself about two-thirds away through the first of a 2-day event, I was getting bored.

Why would I be getting bored? The problems and issues that they were all addressing are ubiquitous in additive manufacturing: need better materials properties, need better inspection capabilities, need better design tools, et cetera.

At the end of the 2 days, my personal synthesis was there are basically two differences in medical applications from all the different things, like what they are doing in GE: sterilization and body biocompatibility. Because of the problems, it makes the importance of an institute focused on additive manufacturing and being able to share across business sectors really relevant.

So we were very pleased when the FDA actually became a signed member about a month ago so they can sweep up the things we are already learning, hear their specific needs, and advance all the technology across the United States.

Mr. LANCE. To the distinguished members of the panel, are we in the advance in this country or do other countries, perhaps in Europe or Asia, have a system that recognizes this to a greater extent than we do in this country?

Mr. MORRIS. It has been interesting in that one of the things that I heard from a good friend, Terry Wohl, who is one of our members, of Wohl Associates, he did some visits at the invitation of the Chinese Government a couple years ago, and they shared that they are doubling down on their national investments in additive manufacturing because they saw what the United States was doing, so they are now surpassing us.

A representative from Singapore visited me personally in Youngstown, Ohio, in our facility in downtown Youngstown, and they have now stood up a center for 3D printing and innovation in Singapore with initial funding of $150 million, more than twice the funding I have.

Mr. LANCE. Thank you. My time has expired, but I hope to be able to purchase this further in the future. Thank you, Mr. Chairman.

Mr. BURGESS. The Chair thanks the gentleman. The gentleman yields back.

The Chair recognizes the gentleman from California, Mr. Cárdenas, for 5 minutes for your questions, please.

Mr. CÁRDENAS. Thank you very much for imparting your knowledge with us on what is going on in this dynamic, fast-changing industry.

The first question is from my wife. When do you think that they will be able to make a husband's brain? I didn't say a human brain, I said a husband's brain to help someone pick up after oneself, remember anniversaries, et cetera. Just kidding, just kidding. That is the impossible, I know.

Now, on a more serious note, we have noticed that in America's libraries we have had an increase of donations and opportunities where libraries are investing in 3D printers now to the tune of over 400 libraries have access to little or no cost to individuals going to the library.

To me, this is a very important issue for making sure that we have access to as many minds and as many inquisitive folks so that they can get turned on to how wonderful it is and the potential of getting a job in the industry.

How committed is the industry to advancing that kind of effort?

Mr. ORRINGER. Well, I can take a shot at this just because we had a little bit of an excess inventory of desktop 3D printers about a year and a half ago. And we didn't rehearse this, by the way. And I had this great idea: Why don't we donate these printers to libraries across the country? With one hitch. I didn't want to donate a couple hundred printers to libraries and have them just sit on a shelf and collect dust. That is a really big problem I see.

So we actually held a competition, we partnered with America Makes, because they know how to do competitions, and had an overwhelming response from all across the country.

We need to do more like this. It is going to pay back dividends. We are struggling certainly still in terms of workforce development, in terms of making sure people have access to this technology. And I strongly believe that if we can start bringing these kinds of tools to young people as soon as possible, that is going to pay dividends in the long run.

So we are strongly committed. I know other folks on this panel are as well. And we will be happy to keep you informed on our progress.

Mr. CÁRDENAS. Yes. That is an investment in human capital and connecting your industry to the minds of the workers of the future.

Yes, Mr. Morris?

Mr. MORRIS. I pay a lot of attention to unintended consequences in what we do. You can do something really admirable, and at the end of the day you are not doing something so admirable. So even with the vision of a printer in every school, we are urgently needing encouragement at all levels of the Government, beginning at the local communities and perhaps in some of the local rotaries, et cetera, foundations and groups that are able to provide some funding.

For example, if we put a 3D printer in Ms. Brown's class and it breaks, who is going to fix it? Who is going to buy the materials? Ms. Brown? That is not very kind.

And for the libraries, same vignette. How do we keep it operating, how do we get the training materials in all the libraries and all the schools, how do we have the resources made available so it is not burdensome when this thing shows up. You can do great things with innovation, but we have to do it wisely.

Mr. CÁRDENAS. Yes. Thank you for pointing that out.

One of the things that I am so proud to be an American is the fact that we have this reputation that when we embark on something and we dedicate ourselves to doing it well, it takes a long-term vision and a long-term commitment. And there are infrastructure costs, there are ongoing costs, et cetera, instead of just the

flash of, for example, the ribbon cutting, giving away printers, and then coming back a year later and embarrassingly realize that none of them are in use because, you just explained, that without the follow-through, they are not doing anybody any good.

Mr. MORRIS. Right.

Mr. CÁRDENAS. And it is a falsehood whenever any of us, whether it is Government or private industry or philanthropically, we do something without looking at the long sight of the issue. So thank you for pointing that out.

But the follow-up on that is I hope that you read into my question, and not just libraries, public schools, et cetera, that the industry actually maps out and shows us how we can either partner or they can take the lead, et cetera, and how we can make sure that we have that available as much as possible to every community in America. Again, it is an investment in human capital, I think.

I want to point out with my limited time here that when it comes to bioprinting, apparently when you look at the 3D printer is used to place bio ink in precise locations, allowing cell types to align themselves in a manner that resembles the origination of native human tissues. These 3D human tissues can then be employed in drug discovery and development, biological research, and therapeutic implants for the treatment of damaged and degenerating tissues and organs, et cetera. You get the picture. This is amazing.

What do you see the top-line issues facing those efforts when it comes to regulatory and technology and world competition?

Mr. MORRIS. I am not competent to address the regulatory issues, but what I will say is I think where our National Additive Manufacturing Innovation Institute can come to play in a very important way in advancing bioprinting, as we do with all the other areas of application of additive manufacturing, is getting from the research to the true product application there is historically what is called the valley of death.

And we have got a structure to cross that valley of death. It begins with pooling a community of the researchers, academics, labs, et cetera, across the Nation, with the end users, and start that discourse of what do you need, where are you going, what are you building, how can we apply it, how can we accelerate it.

And so we do a lot of workshops to do roadmapping, and we would eagerly like to do roadmapping with bioprinting. We have several of our members who are doing some landmark research and development in bioprinting, such as the University of Pittsburgh, Case Western University, et cetera. Team those up with the medical end users, working with our new member FDA, et cetera, to lay out what is the right path, how do we accelerate, what is the funding model.

And then continue to go back to this model of the opportunity to do the key thing in a public-private partnership, and that is share the cost. Where it is high risk, Government money comes into play. Industry needs to invest because they are doing the product application. We think that is a very shrewd model going forward, a public-private partnership with cost share, which is the unique capability of an Additive Manufacturing Innovation Institute.

Mr. CÁRDENAS. Thank you, Mr. Chairman. I yield back.

Mr. BURGESS. The Chair thanks the gentleman. The gentleman yields back.

The Chair recognizes the gentlelady from Indiana, Mrs. Brooks, 5 minutes for your questions, please.

Mrs. BROOKS. Thank you, Mr. Chairman.

And thank you all to your panelists for your actually exciting testimony. I wasn't sure when I was reading this initially.

But I think why this is so exciting is because I think this is the way to draw young people back into manufacturing. We have in central Indiana, in my district, about 50 middle and high schools that have 3D printers that are being utilized in the classroom. Indiana is one of the country's most manufacturing-intensive States.

And then before coming to Congress, I was senior vice president at our State's community college, and where I learned about 3D printing during that time period, but I think we still need to make sure that the adults and the educators who are working with our young people have an understanding about this 3D printing.

I had an event, and we welcomed 3D Parts Manufacturing to educate school counselors at a school counselor event, to try to educate them about 3D printing, because they are the ones who influence our children and get them excited about these things.

So I am curious, in expanding on the public-private partnerships, which I completely believe in, how do we do a better job bringing industry, collaborating with our educators and with either our nonprofits, and try and get the young people more engaged in 3D printing and skills that they need? What are some best practices you have seen? How do we expand this? Because I think it is one of the manufacturing tools of the future. What do we need to be doing better?

And believe it or not, I actually think calling the place where they work maker spaces actually helps because young people are not as interested in manufacturing, I think, as they are in making.

Mr. Morris, you want to start?

Mr. MORRIS. I am wrestling with jeopardizing and putting at risk a very important relationship we have with Elizabeth Forward School District outside of Pittsburgh, Pennsylvania, and Elizabeth Forward. They are a premier benchmark of redefining education in the United States and leveraging the power of additive manufacturing 3D printing to teach.

The risk in the friendship is they are already being inundated with people that want to know what they are doing, because this is the right place to go. So we need to find some way to assist them. And the key thing at this point is communication, communication. We could use more resources to communicate better across the Nation this is what is happening, this is how you do it, this is where we can work together in the public-private partnership model to in very interesting terms infect the United States with manufacturing is back and it is the right place for careers.

Mrs. BROOKS. But if you think about—so, Dr. Herderick, GE is located in so many locations across the country, UPS obviously is, I don't know that your company is yet, but, I mean, what do you view as industry's role in partnering with the education community? And I welcome the fact that you put them into libraries and so forth, but what should we be doing that we are not doing?

Mr. ORRINGER. So I guess I want to, at the risk of contradicting myself, I want to make sure we distinguish a little bit. Ed did this a little bit already. But there is a distinction between what we see in maker spaces and what we see on a factory floor, and particularly when we get into some of the very hardline manufacturing industries such as aerospace and defense and others. And I really think it is important that we embrace both cultures and drive innovation in both areas.

So there is a great company that I work with in Indiana called 3rd Dimension. They have a beautiful shop of many metal 3D printers. They have a whole host of aerospace and defense customers.

They are tied to Purdue. They are not too far away from Purdue, actually. And they are a small business, but they are embracing a whole host of fellowships and internships, getting folks excited, not just about the usual maker kind of space where you maybe play around with tchotchkes and toys, but these massive million-dollar hunks of hardware, to actually see what actually happens on a shop floor and how we are revolutionizing manufacturing, which is a totally different concept.

It is really important that you see both sides of the spectrum. Maybe you could see the maker spaces as a gateway. But if you don't bring in the other part of the equation, then you are missing it.

Because additive manufacturing is a serious business. We are a global company, we are the largest, we are in 50 locations all over the world. People haven't really heard of us. And there is probably a reason for that. The reason is until recently GE wouldn't want to brag that they used additive manufacturing, because they didn't want their competition to know how they made the secret sauce.

And that still takes place. Our first additive manufacturing machine, the serial number is SLA–3. I saw it a couple years ago in General Motors. It was installed there in 1989. This is not a new industry, it is just new to people who are suddenly—so I think the maker space concept is great, because it suddenly captured people's imaginations. Bus is also important when you think about public-private partnerships, encouraging manufacturing, that you also bring people into the fold and understand this is also revolutionizing manufacturing now.

Mrs. BROOKS. Thank you.

Thank you. My time has expired.

Mr. BURGESS. The gentlelady yields back. The Chair thanks the gentlelady and recognizes the gentleman from Mississippi, Mr. Harper, 5 minutes for your questions, please.

Mr. HARPER. Thank you, Mr. Chairman.

And thanks to each of you. It is an amazing technology, and we really are just only beginning to see what all we are going to be able to do in the future.

And, Mr. Amling, I don't have a question, but certainly welcome. UPS was my very first job in my life as a 15-year-old. I loaded an 18-wheeler every night with boxes. And I am the one who packs the trunk on the family trips.

Mr. AMLING. So you learned to work hard.

Mr. HARPER. We know how to build the wall.

Mr. AMLING. Bend at the knees, right?

Mr. HARPER. That is it. And it might have been a 3D component to that as well, I am thinking.

But thank you each for being here.

Dr. Herderick, when GE obtained certification from the FAA for its LEAP jet engines, it was clearly a major accomplishment for additive manufacturing. I am just curious, how many pages of testing data does a company need to rely on in order to obtain that FAA certification for a new item like that?

Dr. HERDERICK. I mean, so our materials testing database that we build up before we take it to the FAA, I mean, it is many hundreds, even thousands of pages. I mean, it represents over a 10-year journey from initial concept. I mean, it was a single engineer, she had an idea in our combustors group for the fuel nozzle looking at machines, and then, of course, it became a cast of many hundreds. And so it was a pretty serious book of knowledge that we took to the FAA, as you might imagine.

Mr. HARPER. It is amazing. I am just curious, what extra effort was needed to show that the nozzles, which was entirely 3D printed, that they were strong enough and did not create a safety risk? How do you go about that?

Dr. HERDERICK. So it all starts with understanding the fundamentals of the process and demonstrating what we would call a stable process. So demonstrating over many, many thousands of cycles. It is not just building one and going out and testing it. It is many years of effort and building many thousands of fuel nozzles and demonstrating that every one is the same coming out of the machine process.

We do post-treatments to heal any defects that come out of the machining process. And then we actually x ray the parts before they go out into service. So each part, we have a 3D image of the part before it goes onto any engine.

Mr. HARPER. And, of course, going through this process, did this help GE learn how to navigate the certification process so that future parts maybe experience a quicker process?

Dr. HERDERICK. It did.

Mr. HARPER. OK. That is great.

How does additive manufacturing fit with and add value to the traditional supply chain? Explain that to me a little better.

Dr. HERDERICK. Yes, it is a great question. So I will talk about the metals technology. So I think a lot of people look at these metal printing technologies and think maybe this could replace casting or replace forging. In reality what we are using it for is to create more valuable, higher performance products during the design phase that then transition to castings and forgings. So really what it is doing is opening up some highly value-added applications, which really truly fit with American manufacturing, high value, complex shapes and parts that we wouldn't be able to design without having the metal prototyping processes during our testing phase.

Mr. HARPER. Right. That is great.

Let's talk about cost for a minute. What kind of cost savings do you think could be achieved if a manufacturer is able to take full advantage of 3D printing and integrate it as fully as possible into supply chain?

Dr. HERDERICK. Well, I think the biggest cost is time to market, so being able to get to market much, much more quickly, and reducing the cost of different iterations of product lines. That is really where we are seeing the biggest benefit: getting to market faster with higher performance products.

Mr. HARPER. Got it.

Mr. Orringer, what method of printing was used to produce the titanium hip implant, and why was this the method best for the implant?

Mr. ORRINGER. Yes. So this is the part we were talking about here, and you can see it is pretty porous. We use a process called—well, we call it direct metal printing. It is powder bed laser fusion, which is kind of a mouthful.

The reason why it is so important—and I actually had to check with my wife who is a surgeon to actually understand fully what we are talking about here. So typically when you make a part like this, it is going to be casted, and you can ultimately cast a pretty solid and dense part. That is going to cause, when you are talking about titanium, stress on a bone.

What we are able to do with 3D printing is we are able to actually design a part that is optimized to both reduce stress on the bone and also be porous enough to get bone to actually grow and actually regenerate, and this can only be done through this process. Typically, what they have done in the past is they will cast this component and they will have a coating on top that is porous. It is relatively superficial. If you can get a densely made part that is also porous, as contradictory as that sounds, you can actually help regenerate bone and help with the growth and not lead to bone stress and——

Mr. HARPER. So this is not only going to be better for that area, but also speed up the healing process.

Mr. ORRINGER. Exactly. Exactly. And we are actually seeing this area explode. This is part of the factory of the future.

Mr. HARPER. Great.

Well, look, I want to say thanks to each of you being here.

I am over my time, I yield back, even though I don't have any time, Mr. Chairman.

Mr. BURGESS. The gentleman yields back. The Chair thanks the gentleman and recognizes the ranking member of the subcommittee, Ms. Schakowsky, for redirection.

Ms. SCHAKOWSKY. Mr. Morris, I had just wanted to ask you a question on how America Makes' work in the health space has the ability to translate into increased access for patients across the country to the advancements that 3D technology has helped to do

Mr. MORRIS. So I am not sure I heard everything there. Excuse me.

Ms. SCHAKOWSKY. Well, I am just interested in your work in the health space and how that is going to advance patients' access to better health care.

Mr. MORRIS. Right. We have got a couple of projects underway and several of our members are deeply involved in medical applications, 3D printing.

Again, the challenge is to get the word out across the Nation in effective ways, so we try to do that communication as best we can.

And there are some interesting things that we have been learning in the process, both in terms of the technology of how you do the inspections and the similarity of problems for making parts for a jet engine versus parts that would be embedded in a body, and then some of the more subtle things, and this is really cross-cutting more the medical.

What you heard in some of the testimony from Neal was the models that were made. So a major use of the technique of that manufacturing is for tooling, to be able to do tooling to adopt the surgery and to very carefully and precisely guide the surgery tools, et cetera.

And then there is something interesting to all of these. One of the key pieces of technology that has come along with 3D printing was 3D scanning. And as I was engaged with a conversation with a research scientist in the medical community. Obviously when you have got a piece of bone missing maybe from a car accident, maybe it is a wounded soldier, and you want to do a 3D scan so that that implant perfectly fits, and this is where that bioreabsorbable piece comes into play. As the bone grows back, the body absorbs the implant, then you don't have to remove the metal implant, which is really clever.

And they pointed out something, which was sort of an "ah-ha, boy, I should have seen this one coming." You want it to match, but you also want it to match this side of the head, because if you make this one a different shape than this shape, you have cursed that person for life.

So there are all these different subtleties that we are communicating with the medical community. The explosive use of the technology is incredible. About one-third of the patents as of 2 years ago were in the medical applications of 3D printing.

Ms. SCHAKOWSKY. Thank you so much. Thanks all of you.

Mr. BURGESS. The gentlelady yields back and the Chair thanks the gentlelady.

I will recognize myself for redirection.

I mean, you all brought it up, so it is going to come up when we go back home. Our schools are going to ask us: Hey, how do we get that for our students? So any of you want to provide some direction and advice to the members of the subcommittee?

Mr. MORRIS. We have initiated 2 years ago a process with DonorsChoose, where donors can go to the Web site and contribute funds and allocate it for 3D printers in their schools or wherever, maybe a Boy Scout troop, Girl Scout troop, et cetera. So that is one mechanism for the public to partner in and put their skin in the game, if you will, to get the printers in the hands of the youth of the United States.

I wanted to also quickly point out another really outstanding benchmarking of using additive manufacturing 3D printing for education is U.S. FIRST in the FIRST Robotics Competitions. Industry has been stepping up in great fashion to tutor and mentor the teams in the FIRST Robotics Competitions. I personally got involved in this attending two of their annual nationwide and global competitions. And we actually set up, we took some 3D printers, and we were doing hospital repair of broken parts in the competition, which was kind of cool.

But that is another excellent model of STEM education, training in all of the aspects of design, including business with this technology, and partnering with industry to put up the deep engineering talent working and mentor the students outside school.

Mr. BURGESS. Very well.

Mr. Orringer, I just wanted to ask you—well, you hear the bells go off. So we had a vote series called. Fortunately, it looks like we have made it through our hearing, and the good news for you is we have got a long series of votes, so it would keep us away for a while. So I think we will be able to adjourn before we go and vote.

This subcommittee does not deal with the FDA, but our full committee does. And it just strikes me as we are talking about things like the templates of the lattice to build new body parts, this really is cutting-edge stuff. And we have a regulatory agency. Yes, They are equipped to tell someone how to go about getting a drug approved, they are equipped to tell someone how to go about getting a device approved, but something that sort of blurs the lines between those two areas may be more difficult.

So have you had any experience, positive or negative, in dealing with the regulatory side of this on your medical side?

Mr. ORRINGER. We are actually certified to build Class I, II, and III devices in our facility in Colorado, which is where our medical modeling facility is placed. And our folks there tell me it is a difficult process, it is difficult to be certified to be able to manufacture these kinds of components. You probably want that, though, to ensure that we maintain the appropriate levels of quality, safety, et cetera.

Mr. BURGESS. Yes. I want to interrupt you just for a second. Yes, you want it, but I want the regulatory agency to be able to provide you direction. What are the steps that I have got to go through? What is the pathway to getting this completed?

And then the complaint that I will hear frequently is somehow the rules all change along the way and then I have got to go back and recertify or reapply.

Yes, I want the devices to be safe. I don't want to hear about things having to be recalled or removed. It is one thing with an automobile, it is a dreadful thing if it is in a child. But we also want to lay out the regulatory pathway for you so that you know and it is predictable, and you know the steps and the sequence, and you know that when you complete the tasks, that is the end of the process, that it is not an endless back and forth, oh, we are going to need more stuff, we didn't ask you this, we are going to need for you to go back and do this for a couple of years and come back and see us.

So when I am saying that this is your subcommittee too, I mean, that is the sort of feedback that I need to hear, the committee needs to hear, our staff needs to hear. We are anxious to have this be a continuing dialogue, because this is the sort of stuff that is over the horizon, but it is really pretty bright. When I talk to medical students, the kids in medical school today are going to have tools that no generation of doctors has ever known.

Mr. ORRINGER. That is right.

Mr. BURGESS. That is pretty powerful.

Mr. ORRINGER. Yes. I appreciate that. We will certainly keep you posted. I think it has already been discussed.

A really huge barrier to entry is just that certification process. Five to 10 years just to introduce a new material, new process into the system. If we can figure out a way to accelerate that process, not only on the aerospace and defense side, but in all of our industries. And I think the FDA, as well as the Department of Defense, have a lot to contribute to this area, and we would definitely appreciate your help in making that dialogue happen.

Mr. BURGESS. Well, thank you.

And, again, thanks to all of you on the panel. It has been a very informative morning.

Seeing that there are no further members wishing to ask questions, I will thank our witnesses for being here today.

Before we conclude, I would like to submit the following documents for the record, by unanimous consent. A statement for the record from the American Chemistry Council. Without objection, so ordered.

[The information appears at the conclusion of the hearing.]

Mr. BURGESS. I would also like to submit a letter from the Specialty Equipment Market Association. Without objection, so ordered.

[The information appears at the conclusion of the hearing.]

Mr. BURGESS. Pursuant to committee rules, I remind members that they have 10 business days to submit additional questions for the record. I ask the witnesses to submit their responses to those questions within 10 business days upon the receipt of those questions.

And without objection, the subcommittee stands adjourned.

[Whereupon, at 11:37 a.m., the subcommittee was adjourned.]

[Material submitted for inclusion in the record follows:]

PREPARED STATEMENT OF HON. FRED UPTON

U.S. manufacturing is recovering slowly from the recent downturn. Automakers in Michigan have weathered the storm and are making a comeback, but the next manufacturing revolution is yet to come.

As Washington overregulation and uncertainty puts downward pressure on American manufacturing, disruptive technologies are quietly pushing the tide in the other direction.

With the Disrupter Series, we seek to highlight what the private sector is doing despite the red tape-and additive manufacturing is an excellent example of this.

Increasingly, the modern factory is becoming digitized. More than ever, part designs, assembly processes and the supply chain as a whole are woven with digital threads that enable companies to closely manage and improve their work.

Building things is the American way, but software is the wave of the future. When it comes to manufacturing, thanks in part to the development of 3D printing, we can say the U.S. has an app for that.

Advancements like 3D printing must be allowed to flourish and must be supported in order to bring American builders from innovative entrepreneurship to world leadership.

While I am pleased to hear about the exciting developments in 3D printing in manufacturing, I am also excited about the potentially life-saving benefits 3D printing has brought to the healthcare sector.

Many of you know of this committee's 21st Century Cures initiative, and 3D printing makes important contributions to the development of vital cures efforts. Although in its experimental stages, bioprinting promises potentially revolutionary advancements and is already being used by scientists to produce human organ tissue, which greatly improves the quality of pharmaceutical testing.

From rapid and accurate prototype models to surgical guides to finished parts and products, we are just beginning to see the impact 3D printing will have.

I look forward to this exciting discussion and thank the witnesses for their participation.

American Chemistry Council
Statement for the Record
House Energy & Commerce Subcommittee on Commerce, Manufacturing and Trade
"Disrupter Series: 3D Printing"
February 26, 2016

The American Chemistry Council (ACC) appreciates the opportunity to comment on the House Energy & Commerce Subcommittee on Commerce, Manufacturing and Trade hearing entitled, "*Disrupter Series: 3D Printing.*" Representing over 180 companies engaged in the business of chemistry, ACC is an innovative $801 billion enterprise and a key element of the nation's economy. ACC members apply the science of chemistry to make innovative products and services that make people's lives better, healthier and safer. The business of chemistry, including manufacturing of lightweight plastics and polymer composites used by the transportation industry, creates over 800,000 manufacturing and high-tech jobs, plus six million related jobs that support families and communities. The products of chemistry, such as plastics and polymer composites, make it possible to provide clean air and water, safe living conditions, efficient and affordable energy sources, lifesaving medical treatments, and safe and innovative transportation solutions. Given the focus of today's important and timely hearing to examine the direction of 3D printing and its impact on jobs and economic growth, ACC would like to share background on work being completed in this important area.

Automotive technology is changing rapidly with the goal of creating more sustainable personal transportation and associated infrastructure. Manufacturers are increasingly utilizing innovative manufacturing technologies and materials, such as lightweight plastic and composite materials, to increase auto fuel efficiency. This trend is likely to accelerate as automakers across the country take steps to meet the Corporate Average Fuel Economy (CAFE) standards. ACC members have been at the forefront of developing products from chemistry - including lightweight plastic and polymer-based materials - to helped increase fuel efficiency, enabled more flexible vehicle designs, created new innovative manufacturing techniques and helped improve auto safety. Plastic and polymer composite products contribute robust and distinct economic benefits to our nation. Produced at 1,572 plants in 45 states, employing over 54,000 people and featuring a payroll of over $2.5 billion, advanced plastics and composites in the automotive sector have doubled in use over the last twenty years.

Composites are a combination of tough plastic resins reinforced with glass, carbon fibers and other materials. These plastic composites are lighter weight than traditional automobile materials, yet can maintain high levels of strength and a high resistance to corrosion. Plastic and composite materials

provide a way to lighten vehicles while maintaining passenger safety and the integrity of the vehicle. Additional properties of plastics and composites, including strength to weight ratio, energy absorption and flexible design, make these materials ideal for use in the manufacturing of vehicles. The high strength and energy absorption of structural polymer composites can also improve crash safety by strengthening vehicle compartments to help protect passengers during crashes.[1]

Additive manufacturing techniques can give the automotive industry new design flexibility, reduce energy use, and shorten time to market. The additive manufacturing process is often called 3-D printing or digital manufacturing because of similarities to standard desktop printing. Additive equipment can use polymers and composites to "print" a range of functional components, layer by layer, including complex structures that cannot be manufactured by other means.[2]

The plastics and polymer composites industry continues to work with the automotive industry to develop manufacturing processes that enable the integration of innovative lightweighting solutions, like additive manufacturing. Additive manufacturing can help automakers design and manufacture more fuel efficient and lightweight vehicles. For example, the use of additive manufacturing technologies can help to develop prototypes that are representative of production parts and evaluate these technologies for full-scale production within the automotive manufacturing environment. The advancement and application of non-destructive testing and evaluation capabilities for plastic and polymer composites can help ensure the integrity for automotive products manufactured through additive manufacturing capabilities.[3]

In 2014, the first combined body and chassis 3D printed car was successfully manufactured almost entirely out of plastic and polymer composites. The "Strati" took 44 hours to make and is completely drive-able. According to its manufacturer, Local Motors, the vehicle is lighter and stronger than its metal counterparts, due to the use of carbon fiber reinforced plastics in the manufacturing process. Carbon fiber reinforced plastics are typically 50 percent lighter than comparable metals with 12 times higher energy absorption.[1d]

Plastics and polymer composites are helping to solve many of our nation's transportation challenges, including those faced by automakers seeking to achieve current and future federal safety standards for vehicles and light trucks. Technological innovation, like additive manufacturing, plays an important role. Together, the plastics and polymer composites industry can successfully harness new and innovative vehicle technology to help auto manufacturers achieve safety requirements, fuel efficiency and contribute to reduced greenhouse gas emissions.

ACC applauds the Energy & Commerce Subcommittee on Commerce, Manufacturing and Trade for its efforts to advance innovative technologies in the automotive sector. ACC supports this work and highlights the increasingly important role of lightweight plastics and polymer composites in manufacturing innovative automotive technologies. We look forward to

continuing to work with the Committee, Congress, and all stakeholders on the development of emerging technologies and manufacturing processes that improve fuel economy and auto safety.

[1] Aviva Brecher and John Brewer, Volpe National Transportation Systems Center, and Stephen Summers and Sanjay Patel, National Highway Traffic Safety Administration, Characterizing and Enhancing the Safety of Future Plastic and Composite Intensive Vehicles (PC1Vs), http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0316.pdf

[2] U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Advanced Manufacturing. " Additive Manufacturing: Pursuing the Promise, Digital manufacturing paves the way for innovation, mass customization, and greater energy efficiency as part of the national all-of-the-above energy strategy", 2012, http://energy.gov/eere/amo/downloads/additive-manufacturing-pursuing-promise

[3] ACC "Plastics and Polymer Composites for Automotive Markets Technology Roadmap," 2014, http://plastics-car.com/Tomorrows-Automobiles/Plastics-and-Polymer-Composites-Technology-Roadmap

# # #

https://www.americanchemistry.com/ The American Chemistry Council (ACC) represents the leading companies engaged in the business of chemistry. ACC members apply the science of chemistry to make innovative products and services that make people's lives better, healthier and safer. ACC is committed to improved environmental, health and safety performance through Responsible Care®, common sense advocacy designed to address major public policy issues, and health and environmental research and product testing. The business of chemistry is an $801 billion enterprise and a key element of the nation's economy. It is the nation's largest exporter, accounting for 14 percent of all U.S. exports. Chemistry companies are among the largest investors in research and development. Safety and security have always been primary concerns of ACC members, and they have intensified their efforts, working closely with government agencies to improve security and to defend against any threat to the nation's critical infrastructure.

February 26, 2016

Chairman Michael C. Burgess
Energy and Commerce Committee, Commerce, Manufacturing, and Trade Subcommittee
United State House of Representatives
2336 Rayburn House Office Building
Washington, DC 20515

The Honorable Jan Schakowsky, Ranking Member
Energy and Commerce Committee, Commerce, Manufacturing, and Trade Subcommittee
United State House of Representatives
2367 Rayburn House Office Building
Washington, DC 20515

Re: February 26, 2016 Hearing: "Disrupter Series: 3D Printing"

Dear Chairman Burgess and Ranking Member Schakowsky:

Thank you for organizing a Subcommittee hearing on how three-dimensional (3D) printing is revolutionizing the way in which U.S. companies manufacture products in the 21st century. Please accept this letter as the Specialty Equipment Market Association's (SEMA) statement for the record regarding the role that 3D printing plays in the specialty auto parts sector.

SEMA represents the $36 billion specialty automotive aftermarket. Our trade association is made up of about 6,800 mostly small businesses nationwide that design, manufacture, distribute and retail specialty parts and accessories for motor vehicles. The industry employs over 1 million Americans and produces performance, functional, restoration and styling enhancement parts for use on passenger cars, trucks, collector vehicles and off-highway vehicles.

3D printing represents the future for manufacturing specialty auto parts, prototypes and tools. In support of this new technology, SEMA offers access to 3D printing through its "SEMA Garage," which helps companies bring products to market faster and at a fraction of what it would cost elsewhere.

Encompassing 15,000 square-feet, the SEMA Garage meets industry demand for a user-friendly resource for testing products to current Clean Air Act emissions standards. The facility also serves as a one-stop shop for product development. Services offered include custom 3D scanning, rapid prototyping via 3D printing, product installation center, photo studios and a product presentation room. Auto parts can be developed, printed, photographed and displayed in one building. Additionally, in partnership with the automakers, companies have access to technical information and measurements allowing 3D printed specialty parts to fit perfectly on the host vehicle.

Using the Garage's state-of-the-art Stratasys Fortus 450mc 3D printer, companies can create a physical prototype that you can see, touch and test, helping eliminate costly changes before the product has gone to production. By utilizing the printer's Fused Deposition Modeling (FDM)

Specialty Equipment Market Association (SEMA)
1317 F Street, NW; Suite 500; Washington, DC 20004
Telephone: 202/783-6007; Fax: 202/783-6024

technology, the printer is able to build products that can endure heat, humidity and chemicals. This cutting-edge technology can accommodate up to a 16" x 14" x 16" part with print accuracy down to plus or minus 5 one-thousandths (+/- .005) of an inch. Printing a product takes a fraction of the time it takes to fabricate the same product through more traditional methods. For instance, an entire intake manifold can be printed in as little as six hours. It's also quite easy.

3D printers are most frequently used for product development rather than mass production. Nevertheless, the technology is becoming more affordable and expanding in capabilities. While polymers are the preferred materials for strength and flexibility, metals may also be available to address higher temperature and pressure needs, among other considerations.

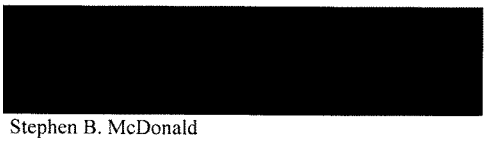
Beyond parts, it is possible to create an entire car using a 3D printer. Local Motors unveiled its second 3D build, the "LM3D Swim," at the 2015 SEMA Show in Las Vegas. "In the past few months our engineers have moved from only a rendering to the car you see in front of you today," Local Motors CEO Jay Rogers told the crowd at SEMA. "We are using the power of direct digital manufacturing to create new vehicles at a pace unparalleled in the auto industry, and we're thrilled to begin taking orders on 3D-printed cars next year." The targeted base price is MSRP $53,000 with a 2017 delivery date. While different formulations and blends are being tested, their current blend for additive manufacturing for the car is 80% ABS plastic and 20% carbon fiber material. Local Motors has plans to open 100 microfactories in the next 10 years, including a location at the National Harbor in Prince George's County, Maryland.

The federal government has played a crucial role in developing the new technology. As a means of showcasing those efforts, the Department of Energy's Manufacturing Demonstration Facility at Oak Ridge National Laboratory in Tennessee printed a 3D Shelby Cobra using the Big Area Additive Manufacturing (BAAM) machine. The car was built with a team of six people in just six weeks. It incorporated advanced composites that cut the vehicle weight in half while improving performance and safety.

In Fort Worth, TX, Painless Performance is producing wiring harnesses for vintage automobiles and off-road vehicles. One of the company founders, Dennis Overholser, remembers selling his first wiring harness at the 1990 Pate swap meet in Cresson, TX. Less than 30 years later, Painless Performance is a multi-faceted company that manufactures over 500 products for show cars, dragsters, rock crawlers and everything in between. Long a SEMA member, Painless Performance, is one of many companies that has taken advantage of the SEMA garage's 3D printing service, which allows them to produce product models they plan to bring to market.

SEMA and its members thank the Subcommittee for its interest in learning more about 3D manufacturing, and the opportunities it offers to improve productivity. Please feel free to contact me at 202/783-6007, ext. 31 or stevem@sema.org if you have any questions.

Sincerely,



Stephen B. McDonald
Vice President, Government Affairs

FRED UPTON, MICHIGAN
CHAIRMAN

FRANK PALLONE, JR., NEW JERSEY
RANKING MEMBER

ONE HUNDRED FOURTEENTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON ENERGY AND COMMERCE

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March 22, 2016

Mr. Neal Orringer
Vice President
Alliances and Partnerships
3D Systems
365 Herndon Parkway
Herndon, VA 20170

Dear Mr. Orringer,

Thank you for appearing before the Subcommittee on Commerce, Manufacturing, and Trade on Friday, February 26, 2016, to testify at the hearing entitled "Disrupter Series: 3D Printing."

Pursuant to the Rules of the Committee on Energy and Commerce, the hearing record remains open for ten business days to permit Members to submit additional questions for the record, which are attached. The format of your responses to these questions should be as follows: (1) the name of the Member whose question you are addressing, (2) the complete text of the question you are addressing in bold, and (3) your answer to that question in plain text.

To facilitate the printing of the hearing record, please respond to these questions by the close of business on Tuesday, April 5, 2016. Your responses should be mailed to Giulia Giannangeli, Legislative Clerk, Committee on Energy and Commerce, 2125 Rayburn House Office Building, Washington, DC 20515 and e-mailed in Word format to **Giulia.Giannangeli@mail.house.gov.**

Thank you again for your time and effort preparing and delivering testimony before the Subcommittee.

Sincerely,

Michael C. Burgess, M.D.
Chairman
Subcommittee on Commerce,
Manufacturing, and Trade

cc: Jan Schakowsky, Ranking Member, Subcommittee on Commerce, Manufacturing, and Trade

Attachment

Attachment - Additional Questions for the Record

The Honorable Gregg Harper

1. Please describe 3D Systems' work in 3D printed prosthetics and fairings. What is the value proposition for using this technology for building parts, digitally tailored to a person's body contours? What other innovations in this area are enabled through 3D printing?

The Honorable Tony Cárdenas

1. America's libraries are rapidly adopting 3D printers and making them available to the public at no-or-low cost. Recent data from the American Library Association shows that 428 public library locations now offer 3D printers, up from about 250 the year before. These libraries are often the only point of access to 3D printers within their communities. How has libraries' democratization of 3D printing technology enhanced its benefit to the public?

2. How might libraries be leveraged more intensively in the future to ensure access to new technologies like 3D printing, especially in low income areas?

3. One exciting way this technology is being used is in the area of 3D bio–printing. This is when a 3D printer is used to place "bioink" in precise locations, allowing cell types to align themselves in a manner that resembles the organization of native human tissues. These 3D human tissues can then be employed in drug discovery and development, biological research, and as therapeutic implants for the treatment of damaged or degenerating tissues and organs. This truly innovative use of 3D printing represents the future of medical research and promises great breakthroughs in therapeutic applications. Innovations like this are the types of scientific advancements the Energy & Commerce Committee is trying to encourage through the bipartisan 21st Century Cures Act. We need to ensure FDA has a clear regulatory pathway and talent to encourage 3D tissue technology adoption and review when products are submitted for approval based on these cutting edge innovations in the next few years. Countries in Europe and Asia have adopted policies that foster the development and approval of innovative technologies like 3D bio-printing. In the U.S., patients and industry remain at a significant disadvantage in accessing the cell and tissue based therapies that will be a critical part of how medicine evolves in the 21st century. Mr. Orringer, we want to ensure that American patients have access to these new and cutting edge therapies. Can you describe how patients will benefit from these emerging technologies and the need for regulatory clarity for innovators and investors when developing products that promise to enhance the practice of medicine?

[Mr. Orringer did not answer submitted questions for the record by the time of printing.]

FRED UPTON, MICHIGAN
CHAIRMAN

FRANK PALLONE, JR., NEW JERSEY
RANKING MEMBER

ONE HUNDRED FOURTEENTH CONGRESS

Congress of the United States

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March 22, 2016

Mr. Ed Morris
Vice President and Director
National Additive Manufacturing Innovation Institute
National Center for Defense Manufacturing and Machining
486 Cornell Road
Blairsville, PA 15717

Dear Mr. Morris,

Thank you for appearing before the Subcommittee on Commerce, Manufacturing, and Trade on Friday, February 26, 2016, to testify at the hearing entitled "Disrupter Series: 3D Printing."

Pursuant to the Rules of the Committee on Energy and Commerce, the hearing record remains open for ten business days to permit Members to submit additional questions for the record, which are attached. The format of your responses to these questions should be as follows: (1) the name of the Member whose question you are addressing, (2) the complete text of the question you are addressing in bold, and (3) your answer to that question in plain text.

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Thank you again for your time and effort preparing and delivering testimony before the Subcommittee.

Sincerely,

Michael C. Burgess, M.D.
Chairman
Subcommittee on Commerce,
Manufacturing, and Trade

cc: Jan Schakowsky, Ranking Member, Subcommittee on Commerce, Manufacturing, and Trade

Attachment

April 4, 2016

Attachment – Ed Morris, America Makes Responses to Additional Questions for the Record

Questions from the Honorable Tony Cardenas:

1. ***School, academic and public libraries are leveraging 3D printing technology to prepare students for participation in STEM fields. For example, at the K-12 level, 3rd graders at the David C. Barrow Elementary School in Athens, Georgia, used their library's 3D printer to design and build their own jewelry as part of a geologic lesson on rocks and minerals. How can the private and public sectors work with anchor institutions like libraries to build critical workforce skills through 3D printing?***
2. ***Los Angeles is a very innovative city, but we are also highly populated. Warner Brothers is using 3D printing to build small-scale models of the locations they are going to use as a pre-visualization tool for the director to determine how the set should be built and to identify the best shot set-up and movement. How can we take advance of this new technology as a tool in urban planning?***
3. ***Government decision-makers are beginning to realize the value of 3D printing technology. NASA recently launched a 3D printer into space to experiment with the creation of spare parts for the international space station, and the U.S. Department of Veterans Affairs recently administered a Prosthetic and Assistive Technology Challenge, through which makers engineered and printed items designed to help veterans with disabilities conquer daily challenges. How can anchor institutions like libraries and schools support government-led 3D printing efforts?***

To provide a more comprehensive response, the following is a combined response to Questions #1 and #3: *"How can private and public sectors work with anchor institutions like libraries to build critical workforce skills through 3D printing," and "how can anchor institutions like libraries and schools support government-led 3D printing efforts?"*

Successfully bringing 3D printing into education is about more than just putting a printer in a classroom. It's about building an ecosystem that includes access to resources, technology, training, curriculum and community. Libraries, including school libraries, public libraries and university libraries, are uniquely positioned to be at the center of this ecosystem.

Libraries are ubiquitous. They are in every state, every city, every county and every school district. Together, the country's public, school and academic libraries represent an unrivaled public infrastructure that decision makers in the public and private sectors can leverage to stengthen our economy and education infrastructure. There are approximately 120,000 libraries in the United States, of which over 16,000 are public library locations. Recent data that the American Library Association collected with the University of Maryland reveals 428 public library facilities that offer 3D printing services. That's a significant number, but even more important than the number is the growth. The 428 figure is up from about 250 the year before – a jump of over 40 percent – and it continues to rise higher all the time.

In school and academic libraries, anecdotes abound of students 3D printing everything from mathematical models, to engine blocks, to robot parts. The leadership of such institutions as the University of Nevada-Reno, which became the first University Library to provide 3D printing and scanning as a library service to all students in 2012, and the David C. Barrow Elementary School, cited in the question above, have set off a torrent of library-driven 3D printing opportunities for learners of all ages.

These opportunities, combined with the myriad of 3D printing activities in public libraries, yield economic, social, and scientific progress in every part of our country. The public and private sectors should work with libraries to expand this progress; specifically, they can pursue opportunities for library partnership and collaboration around 3D printing that promote STEM education, boost entrepreneurship, foster inter-disciplinary and transdisciplinary leaning and build critical workforce skills.

Provide Access to Resources

One of the most important mandates for public libraries is to provide robust, equal access to information and knowledge. Providing access to 3D printing technology like 3D printers, 3D scanners and 3D software is a key way that libraries can play a role in the democratization of learning, creativity and manufacturing. Putting a 3D printer in a classroom provides limited access, but putting a suite of 3D printers, 3D Software and 3D Scanners in a library ensures that not only multiple students, but multiple individuals, multiple classes, multiple teachers, multiples schools and multiple organizations can utlize the technology.

Learners can benefit a great deal from utilizing 3D equipment inside a classroom. Nonetheless, the scope of the knowledge they can pursue in this sort of setting is limited by the strictures of their instructors' lesson plans. When learners use 3D equipment in the informal learning environment of the library, their learning opportunities are limitless; they are free to harness CAD programs, 3D printers, scanners, and whatever else a library might have in its 3D arsenal, to pursue their personal learning passions. If a learner is interested in biology, he or she can print a DNA double-helix; if a learner is interested in paleontology, he or she can print replicas of Jurassic-era skeletal structures. This not only encourages intellectual curiosity, but also facilitates the acquisition of important skills for the modern economy. No matter what a person prints, he or she builds certain basic technical and engineering skills – e.g. how to create a CAD model and how to use plating and slicing programs. When a person prints something in which he or she is personally invested, that person is likely to pay particularly close attention in completing the processes that build these skills. As a result, he or she is likely to achieve higher competence in these skills than someone who 3D prints a compulsory output as part of a set course curriculum. In short, there is a difference betweeen learning and ***connected*** learning – and, moreso than any other education institution, libraries facilitate the latter.

Different types of libraries (whether a public library, a K-12 school library, or a university library) require a different mix of programs and strategies, and a number of suggested opportunities for public and private sectors to support libraries by providing access to resources include:

1. ***Support school libraries with resources and funding to build 3D Printing Labs***
   In order to achieve full integration of 3D printing across STEM subjects, every student in school needs to have access to a 3D printer. While putting one printer in a classroom is a start, a good ratio of students to printers is one printer for every five to eight students in a given class or program. In addition, students need access to more than just a printer – they need access to

CAD software to design and fully utilize the power of the printer, and if possible, 3D scanning technology to learn concepts like reverse engineering. One way to ensure access for all students is by supporting the creation of 3D Printing labs in school libraries. These labs should include computers which have 3D Design Software on them, as well as a suite of 3D printers.

These labs should also include curricular resources that instructors can use to maximize the learning their students can achieve through the printing process. Several 3D printing companies – like MakerBot and Tinkerine – offer discounted product "bundles" to education institutions that include lesson plans. More needs to be done among companies like these to offer pedagogic guidance to libraries and schools that have – or are seeking to acquire – 3D printers. The federal government should also consider making efforts to this end. For example, the Department of Education could consider a program or competition to encourage the development of 3D printed items that solve challenges for learners. Administratively, such a program or initiative could follow the model of Prosthetic and Assistive Technology Challenge, through which the Department of Veterans Affairs encouraged the development of 3D printed items designed to help veterans with disabilities conquer daily challenges.

Ultimately, the goal should be to create synergies between libraries and schools that will give learners full access to 3D technology and pedagogic resources both during structured class time as well as after school. Through these sorts of synergies, libraries will fill in gaps in teacher training, curriculum development and best practice sharing.

2. ***Support School Libraries and Public Libraries to integrate 3D Printers into current MakerSpaces and build new MakerSpaces.***
MakerSpaces are creative, DIY spaces where people can gather to create, invent, and learn. In libraries they often have 3D printers, laser cutters, computer numerical control (CNC) routers, digital production equipment, software, electronics, craft and hardware supplies and tools, and more. MakerSpaces offer opportunity for not only skill building but for project-based learning. Currently, Federal agencies, companies, non-profits, cities, and schools are collectively making commitments to create over 1,000 maker-oriented spaces in the United States, which will expand access to tools and technologies for both students and entrepreneurs. There is an opportuntiy to expand these initiatives with a specific focus on supporting 3D printers in MakerSpaces in school and public libraries, and supporting those spaces with both technology and support materials like 3D Printing filament.

Institutions and agencies have begun to provide funding to encourage the adoption of 3D printers in library MakerSpaces. For example, in response to President Obama's call to make science, technology, engineering and mathematics (STEM) education a national priority in 2010 as part of his Educate to Innovate initiative, the Institute of Museum and Library Services (IMLS) and the John D. and Catherine T. MacArthur Foundation launched the Learning Labs in Libraries and Museums program. This program provided sites in 24 cities and counties with $100,000 each for the planning and design of an "innovative teen space" known as a "Learning Lab." A number of learning labs offer 3D printing services, including those at the Anythink Wright Farms and Anythink Brighton libraries within the Rangeview Library District in Adams County, Colorado. IMLS and foundations across the U.S. should consider supporting similar initiatives moving forward.

3. ***Support Public Libraries and University by providing funding and resources for "3D Printing Check Out Kits."***
   Non-profit organizations like the Boy Scouts, the Girl Scouts and First Robotics, as well as numerous smaller and local organizations can leverage library resources to bring 3D printing to their after school programs. By providing check-out kits that contain 3D Printers, 3D Filament and 3D Scanners, libraries can help organizations expand programming to troops, students clubs and students teams. In the University Library, check-out kits can be accessed by students so that they can use 3D Printing for projects across disciplines including engineering, architecture, art, chemistry and math, among others. Check-out kits are useful for projects that take a print time of 12-hours or longer. The practice of libraries lending hardware to patrons is not new. Some libraries already operate successful check-out programs for Arduino projects (e.g. the Highland Campus Library of the Austin Community College in Texas and the Fond du Lac Public Library in Wisconsin) and mobile HotSpots (e.g. the New York Public Library and the Seattle Public Library). With adequate monetary support, libraries can follow best practices from these ongoing programs to successfully loan "3D Printing Check-Out Kits" to patrons.

4. ***Support University Libraries to build and expand 3D Print Labs, MakerSpaces, Fab Labs and 3D Printing Services***
   Placing 3D printers in univeristy libraries expands opportunities for advancing outreach, teaching and research programs as well as expands student opportunities for trans-disciplinary work across engineering, design, humanities, the sciences and entrepreneuriship. While 3D printers may be housed at different colleges and locations on campus, 3D Printing services and access at a university library ensures that students from across majors and colleges have access to the technology. It also provides opportunties for cross-disciplinary collaboration. Public and Private Partners can work with Universities libraries to develop open access 3D Printing Studios and 3D printing labs. Within the University, University admnistatration can work to ensure that faculty are trained on and familiar with 3D printing technology and provide opportunties for them to learn how this technology can be incorporated and leveraged into the courses, ensuring expanded use of the equipment by teachers and students.

An important note of caution, providing 3D printers must be accompanied by a long-term commitment to provide funding for the 3D printing materials (a consumable for every item created using 3D printing) and on-going maintenance of the 3D printers to keep them operating properly.

Partner with Libraries to support staff training and capacity building

Having technology at a library is one component of the equation to leverage libraries to support STEM integration and build workforce skills, but staff training and capacity building is critical to ensure proper maintenance and usage of the technology. In addition, a trained staff should be able to provide meaningful opportunties for program implementation and engage and educate users – whether the user is a student, a teacher, a professional accessing resources or any other community member. Capacity building also includes best practices sharing on how to stay on the cutting edge of new technology and new offerings and how to properly price usage of the equipment. Public and private insistutions can work with libraries to support staff training and capacity building in the following ways:

1. Public and private institutions can provide funding to organizations like the America Library Association to support staff training and capacity building for librarians through large scale programs that convene librarians and library administrators and allow them to share best

practices on topics like how to create introductory orientiation classses for patrons, or how to plan for and build out a state-of-the-art Library "MakersSpaces" or "Fab Labs."

2. 3D Printer Original Equipment Manufacturers (OEMs), local industry, and local subject matter experts can support libraries by providing volunteers to help maintain the equipment, interns to run library 3D printing programs on a semester basis, and industy experts to support programs.

3. Univeristies can support school libraries and public libraries by including 3D printing courses and certificate programs in bachelors and masters course and degrees, ensuring future librarians, administrators, school librarians and future teachers enter the workforce prepared to bring 3D printing technology into the library.

4. Public and private partners can expand library access to 3D printing curriculum and training through online platforms. One pathway to this is by supporting the expansion of Make It @ Your Library and particularly, expansion of 3D printing content and information on the site. In collaboration with Instructables.com and the American Library Association, Make it @ Your Library created makeitatyourlibrary.org, a website tailored to librarians interested in implementing makerspace projects in their libraries.

5. Non-profit organizations can partner with libraries to leverage 3D printing technology at libraries to help expand their programs to more communities. One example is the e-NABLE Community Foundation. e-NABLE is an international network of passionate volunteers using 3D printing technology to design, deliver, and distribute free upper-limb prosthetics to children and other underserved populations around the world. e-NABLE can partner with libraries across the country who have 3D printing technology to create extended community programs for students and individuals to learn 3D printing skills by printing and building prosthetic hands. Another example is Benetech, a Silicon Valley-based non-profit technology company. Benetech realizes that one of the greatest opportunities for progress on disability issues lies at the confluence of education, technology, science and public policy. They encourage individuals from across these fields – both with and without disabilities – to work together to develop solutions to accessibility challenges. Benetech's latest effort on this front: An IMLS-funded initiative to bring the library, museum and school communities together to level the playing field for learners with disabilities through 3D printing. Last summer, Benetech convened leaders from across these fields in San Jose, California to discuss strategies for implementing the initiative. The convening led to the creation of a "starter guide" for using 3D printed objects in education, and a program proposal for the 2016 SxSWedu Conference, which was accepted, and held in March in Austin, Texas. As impactful as Benetech's initiative has been, it requires additional financial support to continue. Public and private institutions, as well as foundations, can and can continue to back initiatives like this one, so that learners with disabilities can enjoy the opportunities for growth and success that they deserve.

6. Public and private institutions can provide targeted support for rural and small libraries, where demand for 3D technology may be high, but a lack of space, resources and technical know-how may make the adoption of 3D services especially difficult. The popularity of 3D technology is not bounded by urban borders. Individuals living in Manhattan, Kansas are just as likely to be interested in 3D printing, modeling and scanning as those living in Manhattan, New York. Nonetheless, library staff working in areas similar to the former may not feel equipped to administer the hardware and software maintenance, staff and patron training and heavy user

workflow that attends the public provision of 3D printing services. 3D printing companies and agencies like the Department of Agriculture and Department of Education should consider working with the Association of Rural and Small Libraries (ARSL) – a division of the American Library Association – to support technical training and assistance, as well as the provision of 3D equipment and materials, to rural and small libraries in the United States.

Expand, Replicate and Scale Successful Programs and Initiatives

Public and private institutions are investing to expand access to spaces for students and entrepreneurs where they can design, prototype, and make products using technology including 3D printers, 3D Scanners and 3D Software. Public and private institutions can partner with each other and with public, school and university libraries to expand, replicate and scale successful programs. For example:

1. 3D Systems, in collaboration with the Young Adult Library Services Association (YALSA), a division of the American Library Association (ALA), and the Association of Science and Technology Centers (ASTC), is committed to expanding public access to 21st century tools like 3D design, 3D scanning through a program called the MakerLab Club. This program provides up to four printers to libraries that have committed to having trained staff and developing 3D printing programs for the community. It also provides a platform for libraries to share best practices and curriculum. Organizations like America Makes can partner with public and private institutions, industry and OEMs to expand the MakerLab Club and ensure that libraries across the country have access to platform programs and initiatives. According to 3D Systems, over 1300 libraries expressed interest in the MakerLab Club, and over 100 received 3D printers in the first iteration of funding, so there is a great opportunity to expand and replicate the program.

2. The *Department of Education* recently launched CTE Makeover Challenge to transform or create new "21st century maker spaces," in conjunction with their career and technical education programs. This opportunity can be both continued and expanded to focus specifically on makeover challenges at School Libraries.

3. The Economic *Development Administration (EDA)* is spurring regional innovation by supporting the development of maker spaces equipped with the tools, mentors, and programs that allow them to rapidly design and prototype their ideas and bring them to market. Earlier this year, the i6 Challenge of the Regional Innovation Strategies Program issued $10 million in grants to 26 awardees focused on capacity building. This program can be expanded to focus more deeply on maker spaces at public libraries.

4. The *Institute of Museum and Library Services* is working with the Children's Museum of Pittsburgh and other partners to create a framework for effective spaces for making and learning in museums and libraries. Public and private institutions can continue to support and work with IMLS and the ALA to turn frameworks, lessons learned and best practices into hands-on training for library administrators and staff.

5. Universities libraries like the W.E.B. Dubois Library at the University of Massachusetts at Amherst has gone so far as to open a facility entirely devoted to encouraging entrepreneurship through 3D printing. The facility, known as the MakerBot Innovation Center, includes 50 3D printers, and officials there plan to launch an entrepreneur-in-residence program, hold business plan competitions and offer coaching services for start-ups. Public and private institutions can

work across the nation to provide funding and support for centers like these at universities across the country.

Even if a library does not have a facility like a MakerBot Innovation Center that's explicitly dedicated to entrepreneurship, if it offers 3D printing servies, it encourages important contributions to the entrepreneurship ecosystem. Ideas for new products and services are generated all the time. Two major challenges facing any entrepreneur seeking to bring his or her idea to fruition are a lack of access to prototyping equipment and the significant cost of producing a prototype. Libraries that offer 3D equipment eliminate some of these challenges. At many of these libraries, with nothing more than a library card and a brief time investment in completing a training module, entrepreneurs can use 3D equipment and its accompanying design software to bring their ideas into the world for the first time. Generally, the only cost associated with using this equipment for this, or any other purpose, is a modest charge per ounce of material used in the production process. In addition to its low cost, prototyping at the library affords entrepreneurs the ability to create in a safe and friendly environment.

In short, libraries facilitate the procedure of demonstrating proof of concept by relaxing and democratizing the product prototyping process. Recent uses of 3D printing services at the Westport Library in Connecticut illustrate the utility of the library as a space for product prototyping. A woman with no background in business or entrepreneurship used a 3D printer at Westport to prototype a square-shaped headband that imitates the look of wearing sunglasses atop your head. She has now received financial backing and has begun marketing her headband in a variety of colors. Another patron used a Westport printer to a prototype a device that attaches to cell phones and prevents drivers from texting and performing other smart phone functions while operating a car. SafeRide is now being successfully marketed as a downloadable mobile app that locks the smartphones of drivers when they are in motion. Agencies like the Small Business Administration, as well as entities like Small Business Development Centers and chapters of the Service Corps of Retired Executives (SCORE) Association – which already work closely with libraries, in some cases – can work with libraries to publicize and support the work libraries do to help people bring their ideas for new products into the world for the first time.

In conculsion, libraries are leading the way towards the "democracy of creation" and through access to resources are engaging patrons to move from the "information age" to the "imagination age." Cross-sector collaboration and partnerships between government, industry, non-profits, academia and the library community will help to accelerate awareness and adoption of 3D printing technologies and applications across the United States.

Response to Question #2: ***"How can we take advance of this new technology as a tool in urban planning?"***

Summary Response:

To further accelerate the use of 3D printing technology as a tool in urban planning, new projects can now afford to require the creation of 3D printed physical models for evaluation and design optimization. Both large and small projects can now take advantage of the significantly reduced time and cost to produce physical 3D models.

The 3D printer OEMs have identified this market as a sales opportunity and are therefore promoting the technology for urban planning and are working with Universities to include 3D printing training for architects and urban planners.

Explanation:

It has long been a standard practice for architects and urban planners to create three-dimensional (3D) models of their design concepts in cases where the cost and time to create the models was justified by the cost and potential risks for a construction project.

Prior to the use of computer-based design tools, architects and urban planners created two-dimensional (2D) drawings to develop and define their designs. The drawings were historically known as "blue prints" due to the final color of the paper used in the past to reproduce the original master drawings. Converting the 2D drawings to 3D scale models made it much easier to visualize the end product and refine the design. The 3D models are also significantly easier for the client or customer to assess and accept the proposed designs. The changes made during the design optimization process must then be incorporated as revisions to physical model and the master drawings and blue prints.

However, creating the 3D architectural and urban models has traditionally been a time consuming, labor intensive, expensive process. Skilled modeling artisans used wood, thin cardboard, foam board, carved Styrofoam, and other modeling materials to create properly dimensioned scale models of the designs from the original 2D renderings for evaluation. Even after computer software programs for buildings and urban infrastructure designs advanced from 2D computer-based drawings to 3D computer-based models viewable on the computer screen, physical 3D models were made using traditional manual methods. In this case, changes to the design that could be rapidly made in the computer meant delays and increased cost to change the physical 3D model for final evaluation and acceptance by the client.

Combining 3D computer-based models with the ability to rapidly and affordably create physical models using 3D printing, architects and urban planners are now rapidly embracing additive manufacturing to create high fidelity models. Benefits cited by Stratasys for 3D printed architectural models include reducing lead times by 50 to 80 percent, reducing the cost of the models by 40 to 75 percent, and increased model stability over time, eliminating distortion. Another benefit is the ease of updating the physical 3D model by updating the computer model and rapidly printing the refined physical models.

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ONE HUNDRED FOURTEENTH CONGRESS

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March 22, 2016

Dr. Edward Herderick
Additive Technologies Leader
Corporate Supply Chain and Operations
General Electric
221 East 4th Street
Cincinnati, OH 45202

Dear Dr. Herderick,

Thank you for appearing before the Subcommittee on Commerce, Manufacturing, and Trade on Friday, February 26, 2016, to testify at the hearing entitled "Disrupter Series: 3D Printing."

Pursuant to the Rules of the Committee on Energy and Commerce, the hearing record remains open for ten business days to permit Members to submit additional questions for the record, which are attached. The format of your responses to these questions should be as follows: (1) the name of the Member whose question you are addressing, (2) the complete text of the question you are addressing in bold, and (3) your answer to that question in plain text.

To facilitate the printing of the hearing record, please respond to these questions by the close of business on Tuesday, April 5, 2016. Your responses should be mailed to Giulia Giannangeli, Legislative Clerk, Committee on Energy and Commerce, 2125 Rayburn House Office Building, Washington, DC 20515 and e-mailed in Word format to **Giulia.Giannangeli@mail.house.gov.**

Thank you again for your time and effort preparing and delivering testimony before the Subcommittee.

Sincerely,

Michael C. Burgess, M.D.
Chairman
Subcommittee on Commerce,
Manufacturing, and Trade

cc: Jan Schakowsky, Ranking Member, Subcommittee on Commerce, Manufacturing, and Trade

Attachment

GE

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Additive Technologies Leader
Advanced Manufacturing Initiatives Group
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Chairman Burgess,
Thank you very much for the opportunity to present views on the disruptive nature of additive manufacturing at your recent "Disruptor Series: 3D Printing" committee hearing. Responses to additional questions for the record are included below.

Sincerely,

[redacted]

Edward D. Herderick
Additive Technologies Leader
GE Corporate Supply Chain and Operations

The Honorable Gregg Harper

1. What kinds of cost savings do you think can be achieved if a manufacturer is able to take full advantage of 3D printing and integrate it as fully as possible into its supply chain? How do you think these cost savings will benefit consumers?

   The cost savings for additive integration can be dramatic. For example, GE Aviation is targeting a 25% reduction in lifecycle cost for our new CFM LEAP series of aircraft jet engines that power the Boeing 737-MAX line of aircraft. Those savings represent improvements in fuel efficiency and emissions reductions that dramatically improve the environmental footprint of engine operation and are the foundation for affordable air travel for years to come. Those savings are enabled through advanced design creating additive parts that could not be made any other way.

   Another way this will impact consumers is in the healthcare market. At GE Healthcare, we are working on projects to improve the cost for CT scanners using additive metal printing leading to more affordable healthcare solutions for consumers. Again, in this

case additive manufacturing can create high tech components that could not be made any other way.

The Honorable Tony Cárdenas

1. 3D printing has spawned an international maker movement. People and businesses are harnessing this technology to engage in creative learning, build functioning prosthetics, engineer human organs, and more. How can we make sure that the policy frameworks that take shape around this technology --- in such areas as intellectual property, product liability and free expression --- encourage, rather than stifle, the creativity this movement has sparked?

   This is an essential and fundamental question that this exciting field is faced with. The promise of 3D printing is very much wrapped up in an ability to revolutionize design of new products. Thinking about policy frameworks, much of the need rests with broadening an understanding of where the technology is today and how that fits into different markets. For example, the maker movement has been largely centered on mass customization of polymer components for consumer and home applications that would originally be manufactured using injection molding or another mass plastic manufacturing technique. In that space, design creativity is the driver, not necessarily performance in demanding environments. In regulated industries like aerospace and healthcare, a robust framework for verification and validation of additively built parts by agencies like the FAA and FDA are supporting the growth of this industry today and continuing investment of resources will provide a foundation for future growth.

2. 3D printers make valuable tools for innovators. They can be used to build prototypes of novel items at all levels of intricacy. How can we make this technology more available to individuals who have good ideas, but no idea how to bring them into the world for the first time?

   Supporting public private partnerships like America Makes is a great start as are demonstration centers like the MDF at Oak Ridge National Laboratory. Many of the polymer additive machines are very accessible, however the industrial metal machines can be prohibitively expensive for individual innovators. Supporting training programs where innovators can gain access to design software, industrial equipment, and have the ability to test out their concepts would increase accessibility. It also ties back to ensuring that innovators who have an interest in regulated industries like aerospace or medical applications understand the qualification and certification requirements. In that way, they can focus their efforts in areas that do not have the same barriers to entry.

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